REVISION OF THE PALÆOCRINOIDEA.

BY CHARLES WACHSMUTH AND FRANK SPRINGER.

PART III.

DISCUSSION OF THE CLASSIFICATION AND RELATIONS OF THE BRACHIATE CRINOIDS, AND CONCLUSION OF THE GENERIC DESCRIPTIONS.

INTRODUCTORY REMARKS.

During the five years that have elapsed since the publication of the first part of this work, great progress has been made in the study of the Crinoids, both recent and fossil, and many new and interesting forms have been discovered and described.

A number of publications have appeared, which must be regarded as among the most important contributions that have ever been made to the literature of the subject. During the course of our studies for the present paper, we have had the benefit of these discussions and researches, in many instances through the personal kindness of our scientific friends. We have been especially favored in this respect by receiving from Dr. P. Herbert Carpenter many of the proof-sheets of plates and text, in advance of publication, of his magnificent work on the Crinoids of the Challenger collections. This has been of the utmost value to us, and we feel that we cannot be too grateful to the distinguished author for his courteous attention.

We may be pardoned for alluding to the satisfaction we have felt at the kind reception our work has met, at the hands of our co-laborers both in this country and in Europe. That our views would encounter criticism, was expected, and indeed desired by us. The criticisms have for the most part been made in a true scientific spirit, with a view to elucidating the truth. They have in many cases been of value to us, and have enabled us to review the questions raised in a new light. As a matter of course errors on our part have been discovered and pointed out.

In the meantime we ourselves have learned a great deal more about Crinoids than we knew at the time we wrote our first part, independently of the discussions and criticisms above referred to. We have now a far more complete collection of the literature

than existed in the United States at that time. Our materials for study in the way of specimens have also been greatly augmented, and for many of the advantages we possess in this respect we are under extraordinary obligations to the naturalists and collectors of the United States and Canada. Many of these gentlemen, with rare liberality, have placed their collections at our disposal, and forwarded to us, at the risk of loss in transit, unique, valuable and original specimens. We desire to express our grateful thanks for favors of this kind to Prof. Whiteaves, Director of the Canada Survey; Prof. Whitfield, of the American Museum, New York; Dr. C. A. White, of the Smithsonian Institution; Prof. Worthen, Director of the Illinois State Survey; Mr. Walter R. Billings, of Ottawa; Mr. S. A. Miller and Prof. Wetherby, of Cincinnati; Mr. I. H. Harris, of Waynesville, O.; Mr. William Gurley, of Danville, Ill.; Mr. R. R. Rowley, of Curryville, Mo.; Mr. James Love, of Burlington, Iowa, and others. We are also under great obligations to our friend, Orestes St. John, who executed the drawings which illustrate this paper. We consider ourselves peculiarly fortunate in enlisting the co-operation, for this purpose, of one who is both a trained and able naturalist and a skilful artist.

As a result of our recent researches, we have naturally been led to entertain new ideas, and in some cases to a modification of views at first entertained.

In the present paper, which appears as Part III of the Revision, we give a description of the genera that have not been considered in Parts I and II, and shall also state the results of our further studies in their bearing upon the genera heretofore discussed.

In the beginning of this work we recognized two great divisions among Crinoids, viz.: Palæocrinoidea and Stomatocrinoidea, for the latter of which we afterwards adopted Carpenter's preferable name Neocrinoidea. We divided the Palæocrinoidea into three great families, based upon as many distinct plans of structure. We did not at first undertake to identify the different subgroups into which these might be divided, except provisionally in some instances, although we recognized the propriety of such subdivision. Prof. Zittel had established twenty-two families of Crinoids, and while his classification has great merit, and is in many essential particulars in accordance with our own views, it

was defective in not recognizing the more comprehensive relations which exist among these animals. His groups failed to express the distinctions in plan of structure, which we have pointed out. While we are satisfied that the necessities of classification require the recognition of a large number of family groups, which we have not hitherto sought to define, we are more than ever convinced that the three great groups which we originally established, are the only really reliable ones, for the reason that they are founded upon well-defined plans of structure.

The Plates of the Abactinal System.

Dr. P. Herb. Carpenter in his Challenger Report, p. 1, describes "the organization of a Crinoid to be broadly divisible into two well-marked portions," to which he applies the general names "ambulacral and antiambulacral." The ambulacral portion is "the visceral mass or disk in which is situated the whole of the digestive tube with both its terminal openings, and it contains the central ends of the radial water-vessels and blood-vessels." The antiambulacral portion "consists of the stem and its appendages, the calyx, and the skeleton of the rays, arms and pinnules." The two portions, he states, correspond on the whole to the actinal and abactinal systems of Echinoderms generally, and were developed, respectively, around the left and right water-tube, or what are generally called the left and right larval antimers. The whole of the calyx and the arm skeleton are formed on the right antimer; the disk and the extensions of the peristome, and the perisomic plates clothing its ventral surface, on the left antimer.

In all recent Crinoids, and so far as known, in all Neocrinoids, the calyx is restricted to the dorsal side of the Crinoid, and all structures along the ventral side form a part of the disk or its extensions. The calyx consists of few plates, as a general rule only of basals and radials. Comparatively few genera have underbasals. Interradials have been described only in *Guettardicrinus*, in a few species of *Apiocrinus*, in *Uintacrinus*, and in the remarkable recent genus *Thaumatocrinus* which exceptionally also has anal plates. None of these plates, however, extend beyond the limits of the dorsal cup.

In the Palæocrinoidea the structure of the calyx is much more complex. Underbasals are represented in nearly one-half of the

known genera, and all have interradials, by means of which frequently a large series of arm plates are incorporated into the calyx, and thereby elevated to the rank of radials. The term "calyx," although applied sometimes in a general way to the whole skeleton exclusively of arms and column, has been of late restricted to the dorsal cup, and all structures upon the ventral surface were called variously vault, dome or disk. It has been the general opinion that all plates located ventrally, in analogy with the Neocrinoidea, either were perisomic, or at least formed a part of the actinal system. This is the view expressed by Carpenter in the Challenger Report, and we must acknowledge it was our own until quite recently. We now hold that a large part of the ventral surface, throughout the Palæocrinoidea, was covered by abactinal plates, and that the calyx extended to the summit pieces, the so-called "apical dome plates." In this sense the term "calyx" will be used by us in this part of the Revision, while the plates beneath the free arms comprise the "dorsal cup." We further use the term "ventral disk" exclusively to denote the upper surface of the visceral mass, in which the mouth is situated, and from which the food grooves radiate outward. The "disk" is clothed by the "perisome," which may be exposed to view or subtegminal, simply membranous or studded with plates; if subtegminal, it is covered by the "vault," which may be rigid or pliable.

The name "*Camarata*" is proposed for all Palæocrinoidea in which the lower arm plates are incorporated into the calyx by interradial plates, and in which all component parts of the test, dorsally and ventrally, are solidly connected by suture.

Under the name "*Articulata*" we include those families in which the plates of the test are united by loose ligaments or muscles, and in which they are somewhat movable.

The name "*Inadunata*" is proposed for all Palæocrinoidea in which the arms are free above the first radials and which have five single interradials, located ventrally.

These groups will be better defined at the proper place.

A. *The Basals and Underbasals.*

The basals are represented in the Palæocrinoidea by one or two rings of plates. The basals proper constitute the first ring beneath the radials; the second or proximal ring contains the underbasals.

There is, however, one exception to this rule, presented by the remarkable genus *Acrocrinus* (Pl. 6, fig. 1), in which the basals and radials are separated by from four to fifteen rings of small pieces, their number varying in species, and increasing in the growing Crinoid.

The plates of the basal ring are laterally connected except in the two genera *Zeacrinus* and *Calpiocrinus.* In the former they are small, trigonal, acuminate pieces, which externally, and also at the inner floor of the calyx, are separated by the radials, which with their truncated lower angle meet the underbasals. In *Calpiocrinus* four of the basals seem to be totally absent externally, and only the posterior one is represented by a small quadrangular piece. The underbasals differ considerably in size, and are frequently covered entirely by the column. In such cases it is often exceedingly difficult to distinguish them from the upper stem joint. Several species have been described with underbasals which do not possess them, and *Heterocrinus* and *Glyptocrinus* were thought to contain species with underbasals and without them.

Considering the importance that has been given to the presence of underbasals in classification, and the difficulty of identifying them in some groups, it is of some importance, that we have discovered a method, by which, in most cases, the presence or absence of underbasals can be ascertained accurately from the column, the position this occupies toward the general symmetry of the calyx; from the outer angles of the stem joints, their position and that of the cirrhi, whether these are radial or interradial, and from the direction of the rays in the axial canal. The following rules prevail:—

1. In species with underbasals, whenever the column is pentangular, its longitudinal angles are directed interradially, the sides and columnar cirrhi radially; on the contrary, in species with basals only, those angles are radial, the sides of the column and the cirrhi interradial.

2. When there are underbasals and the column is pentapartite, the five sections of the column are radial, the longitudinal sutures interradial, the radiation along the axial canal radial; but the opposite is the case when basals only exist.

For further particulars we refer to our diagrams on Plate 6, which represent species of widely different groups; and we will

state that, notwithstanding we have made the most scrupulous researches throughout our extensive collections and closely examined the descriptions and figures, we have not found a single exception to this rule among all Palæocrinoidea. There are slight deviations, caused by the quadrangular form of certain columns in species which have otherwise a pentamerous symmetry, but we find this also among the basals, which, when composed of four pieces, cannot be strictly interradial.

Among Neocrinoidea, our investigations could be extended only to comparatively few genera, as unfortunately these forms have either a round column or a circular canal. Only in a few species of *Pentacrinus*, *Millerocrinus* and *Apiocrinus* did we succeed in making out one or the other of these points. In these genera, underbasals are said to be absent, but, curiously enough, the outer angles of the column are interradial, the cirrhi and radiation along the axial canal radial, exactly as in the column of Palæocrinoidea with underbasals, and what is more remarkable, as in *Extracrinus*, in which, on the contrary, underbasals are said to be present. The latter seems to suggest that probably many Neocrinoidea either possess small underbasals, or these were present in their larval form. This view is strengthened by the fact that underbasals have been found lately in the younger stages of many Ophiurids and Asteroids.

From our observations it is proved conclusively that the underbasals are not developed from the upper stem joint, as had been supposed by some writers, but represent an independent element, as shown by the fact that the longitudinal sections in Crinoids with a quinquepartite column, always alternate with the proximal plates in the calyx. It is also now apparent to us that the underbasals are morphologically of greater importance than has been generally supposed.

Carpenter's important discovery that the basals represent the genitals, the first radials the oculars of the Echini, and consequently that the proximal radial ring of plates in dicyclic Crinoids cannot be basals, has been now generally conceded by European naturalists, while in America it has been accepted only by Prof. Wetherby, Prof. Williams and ourselves, although no objections were urged against it until lately by S. A. Miller. The latter, instead of attempting to prove the falsity of Carpenter's views, makes the singular remark that the use of the term underbasals,

in describing species " has given rise to the expression " " underbasals obsolete," " which everyone must concede is ridiculous." Is the phrase " subradials unrepresented " or " obsolete " less ridiculous to Mr. Miller, especially considering that those plates are interradial in position? He further says: "The policy of changing the nomenclature may well be doubted." "The claim is made that the change will bring the nomenclature used in defining recent Crinoids in conformity with that used in describing fossils, but as long as this is doubted, it is better to adhere to the established or prevailing methods of description." We cannot see what this has to do with recent and fossil Crinoids. If it is right in the one group it is right in the other, for they are built fundamentally on the same plan. The question is simply this: In Crinoids with a dicyclic base are the plates of the proximal ring or those of the inner ring the homologues of the basals in monocyclic Crinoids? If the latter is the case, and we think it has been most satisfactorily proved by Carpenter, the term basals should be applied in all cases to the interradial ring, no matter what the " prevailing methods " have been heretofore. Certainly Mr. Miller would not call the anus of fossil Crinoids the mouth, for the reason that it was called so by the most eminent earlier writers. Besides, the term " subradials " is illogical, as the plates to which the name was applied are interradial in position.

In the Neocrinoidea, the basals, with the exception of *Hyocrinus*, consist of five pieces, and in comparatively few cases an anchylosis took place. In the Palæocrinoidea, however, among Crinoids with a monocyclic base, anchylosis of two or more of its plates is the rule. We find five basals only in Silurian genera, but associated with one genus having four. Four basals do not prevail beyond the Devonian, and apparently not beyond the middle portion of it. Three basals commence in the Upper Silurian and continue to the close of the Subcarboniferous, while two basals are found exclusively in the latter epoch.

The number of underbasals is five, with but few exceptions. *Xenocrinus* has four; the *Ichthyocrinidæ*, *Gissocrinus*, *Lecythiocrinus*, *Tribrachiocrinus*, three; while in the Carboniferous *Stemmatocrinus* the underbasals form a perfectly anchylosed disk. The latter was taken by Carpenter to be a top-stem joint, an interpretation which we cannot accept, but as we

discuss this question under *Stemmatocrinus*, we need not enter upon it here. An anchylosis of the underbasals occurs also in *Agassizocrinus* by the deposition of new material around the outer surface before reaching maturity, by means of which the sutures externally and internally become obliterated. The same is the case with the basals in *Edriocrinus.*

In cases of three unequal basals, the position of the smaller plate varies among the different orders, but is unchanged in the same one. In all Palæocrinoidea this plate is located between the anterior and *left* postero-lateral ray (Pl. 6, figs. 21, 25, 26); in the Blastoidea between the anterior and *right* postero-lateral ray (Pl. 6, fig. 24); in the recent genus *Hyocrinus* immediately to the right of the anus (Challenger Report, p. 218). In genera with only two basals, such as *Dichocrinus*, *Talarocrinus*, *Pterotocrinus* and *Acrocrinus*, the interbasal suture passes from the posterior to the anterior side (Pl. 6, fig. 3, and Pl. 9, fig. 1). When there are three unequal underbasals, as in the case of the Ichthyocrinidæ (Pl. 6, fig. 23), and in *Tribrachiocrinus* (Pl. 6, fig. 5), the smaller one is placed anteriorly.

B. *The Radial and Arm Plates.*

With the exception of *Acrocrinus*, the radials proper, the representatives of the oculars, constitute the first row of plates succeeding the basals, with which they alternate. In most of the Palæocrinoidea they do not form a continuous ring, being interrupted posteriorly by an anal piece, and sometimes by additional plates, while in some groups all five radials are separated by five interradials, so as to form jointly a ring of ten plates around the basals. In the Palæocrinoidea generally, the radials and their associates are united by suture with each other and with the basals. In *Cromyocrinus* the union is by syzygy, but in a few of the later Poteriocrinidæ those plates are provided laterally, and toward the basals, with more or less deep fossæ, which suggest a less close union and a certain degree of mobility. In some species of *Forbesiocrinus*, *Ichthyocrinus* and *Taxocrinus*, and probably in the Ichthyocrinidæ generally, the radials were united with one another by muscles; with the interradials, however, by ligament, their lateral faces being provided with deep fossæ and dentations along the edges. (Pl. 5, figs. 3–5).

In some Silurian genera, the radial at the right posterior side

makes an exception to the general rule, by either not touching the basals at all, or only toward the right, as in most of the Poteriocrinidæ and Cyathocrinidæ, while the lower left side abuts against the azygous plate.[1] In still others, one or more of the radials are compound, consisting of two sections, horizontally connected by suture, which, combined, have about the form and size of the adjoining single radials, and are succeeded by the same number of brachials as the others. This peculiar structure, which to some extent disturbs the general symmetry, and which occurs throughout different families, but only among Silurian and Lower Devonian genera, is evidently of some importance as representing a very early phase of these Crinoids. The lower segments are probably embryonal plates, which were resorbed by the upper segments, *i. e.*, the permanent radials; in a similar manner as the azygous and anal plate are resorbed by the right posterior radial, which in most of the earlier Inadunata either is missing, as in the case of *Baerocrinus*, or, as in others, imperfectly developed. In *Baerocrinus*,[2] one of the earliest known Crinoids, the azygous piece forms a continuous ring with its four radials, and has the same proportion. In the allied *Hoplocrinus*, however, the right upper corner of the azygous plate is absorbed and replaced by a small trigonal arm-bearing piece, the right posterior radial; the left corner of the plate remaining intact. This is taken up by the anal piece in *Hybocrinus*. In *Dendrocrinus* the azygous plate is reduced to the size of the posterior radial, with which it is connected by a horizontal suture. In *Homocrinus* this suture assumes a sloping position, thereby again decreasing the proportions of the azygous plate. In *Poteriocrinus* the latter is reduced to quite a narrow piece, and the radial toward the right is almost as large as that on the opposite side. In *Cyathocrinus* and *Graphiocrinus* the azygous plate has disappeared entirely, and both posterior radials are equal in size, but separated by an anal piece. In

[1] The term "azygous plate" is used here, and throughout Part III, exclusively for the unsymmetrical lower plate of the posterior (anal or azygous) interradius, the so-called "first anal plate" of most American writers. We reserve the term "anal piece" for the plate enclosed within the ring of radials.

[2] For further information on *Baerocrinus* and the gradual resorption of the azygous and anal plate in the Inadunata generally, we direct attention to our paper on *Hybocrinus*, *Hoplocrinus* and *Baerocrinus*; *Amer. Journ. Sci.*, 1883, vol. xxvi, p. 365.

Erisocrinus the anal plate also is resorbed, and all five radials are perfectly uniform.

Comparing the gradual reduction of the azygous piece, from a strictly radial non-arm-bearing plate to its ultimate resorption by the right posterior radial, with the modifications which the lower sections of the compound radials undergo among species, it appears to us that the azygous piece may represent the lower segment of the posterior radial. This is further suggested by the genera *Anomalocrinus* and *Heterocrinus*, in which the azygous piece, upon its truncate upper side, supports the right posterior radial, which has the form and position of the upper section of the compound radials; while the azygous piece has the form of their lower section. The respective plates in both cases resemble each other so closely, jointly and separately, that they were all described as radials.

In the Actinocrinidæ, Platycrinidæ, Rhodocrinidæ, and in all groups in which the general symmetry is not disturbed by the presence of an azygous plate, the radials are more or less equal in size, the only remarkable exceptions being the Catillocrinidæ and Calceocrinidæ. In *Catillocrinus* only the two antero-lateral radials are approximately alike. All the others differ widely in shape and size, and while these two plates support from fourteen to thirty arms each, the three others have rarely more than one. Another peculiarity of this genus is that it has no axillary plates, all the arms being given off directly from the radials without the assistance of brachials. *Calceocrinus* has but three radials, of which the anterior one is composed of two parts, which, however, are not always continuous.

Our view, that the arms fundamentally commence with the plate above the first radials, whether this is free or incorporated into the calyx, has been fully accepted by P. H. Carpenter, Chall. Rep., p. 48, who further proves it by the developmental history of the plates. The outer radials, he states, " commence as imperfect rings, which soon become filled up with lengthening fasciculated tissue, just as in the case with the stem joints and later brachials;" but " the first radials, like the basals and orals, commence as expanded cribiform films." He further agrees with us that in practice, for purposes of description, it is more convenient to regard the arms as commencing with the first free plate, provided their real nature is not lost sight of.

The mode of union between the higher radials is either by suture or articulation. A sutural union is found in the Actinocrinidæ, Rhodocrinidæ, Platycrinidæ, Eucalyptocrinidæ, and all genera for which we propose the collective name Camarata. Union by articulation prevails in the radials of the Ichthyocrinidæ, Crotalocrinidæ and the Articulata generally. In most of the Ichthycrinidæ, the transverse faces had muscles and ligament so as to permit motion in all directions (Pl. 6, figs. 3, 4). The lateral faces contain deep fossæ, surrounded by a dentated margin (Pl. 6, fig. 5). P. H. Carpenter and other writers express the opinion that in *Platycrinus* also the first radials were united to the outer plates by articulation. They evidently were led to this supposition by some of the figures, which show what appears to be a transverse articular ridge, but which really marks out the inner end or termination of the small wedge-shaped second radial. This plate, in many of the Platycrinidæ, does not extend out to the end of the scar, the remaining part being only covered by the third plates. We have examined thousands of detached radials of this genus, which indicate plainly that the union was in most of the species by syzygy, and this explains why the upper radials became so generally detached. Others are joined by a more or less close suture, but none by muscles.

The primary radials of the Camarata consist as a rule of three plates, exceptionally of two or four. *Platycrinus* generally has two, but here the second and third evidently were anchylosed. Many plates show a depression indicating the former suture, which in some of the earlier species is yet visible. The second radial of *Stereocrinus* has the proportions of the combined second and third of the allied *Dolatocrinus*, and the same is true with regard to *Anthemocrinus* and *Eucrinus*. In *Batocrinus* the second radial is short, linear, and found occasionally anchylosed with the third. Four primary radials occur in *Reteocrinus*, and also in the imperfectly known *Schizocrinus*. From Hall's figure of *Schizocrinus heterodactylus*, N. York Palæont., i, Pl. 28, fig. 3 *a*, it would appear as if the first and second plate combined were equivalent to the first radial in other genera, and here, as in the case of *Heterocrinus* and *Hoplocrinus*, composed of two parts.

In the Articulata the numbers of their primary radials is more variable, and the presence of four radials by no means the exception; but four are often associated in the same specimen with

three or five. *Taxocrinus Egertoni* Phill. (Geol. Yorksh., Pl. 3, fig. 39), even has seven in one, and six in another ray. *Onychocrinus* very frequently has five, *Ichthyocrinus* generally three and four in alternate rays, *Taxocrinus* three or four, *Forbesiocrinus robustus* three and two, and *Pycnosaccus* two as a rule. *Forbesiocrinus Agassizi* sometimes has two primary radials in one or more of its rays, most frequently three, but very often four, and all are articulated on a similar plan.

The secondary and higher orders of radials in the Camarata rarely consist of more than two plates, sometimes, however, of one, three or even four. Only *Glyptocrinus*, *Reteocrinus* and allied genera sometimes have a larger number. In the typical Actinocrinidæ, which branch from alternate sides, the higher orders consist as a rule of a single piece to each division of the ray, which always at the one side supports the radial of the succeeding order, at the other a row of brachials. The latter, however, as should be expected from the term, are not free, but connected laterally by suture with their fellows of alternate orders. In the Ichthyocrinidæ, the higher orders of radials agree in number and form, more or less, with the primary ones, and all are similarly articulated.

Free rays are found as a rule in the Platycrinidæ; in *Eucladocrinus* they extend to nearly the full length of the ray, giving off alternately from every second or third plate an arm, and two at the distal end. Similar rays are formed in *Steganocrinus* and in *Melocrinus;* among the Rhodocrinidæ in *Ripidocrinus.*

The arms of the Camarata bifurcate in their free state only in the genera which Zittel included under the name Glyptocrinidæ, in the Rhodocrinidæ, and in a few Actinocrinidæ, but all branch at least once in the calyx. In all young specimens, as well as in the earlier forms, the arms are composed of a single row of plates, which gradually, embryologically and paleontologically, turn into wedge-shaped pieces at the distal end, or even interlock, while in all later genera the arms are composed of alternate joints. In the Upper Silurian, the biserial arm structure predominates and there is not a single species with uniserial arms in the Devonian. Among the free arms there are no syzygies, but every joint in this group bears a pinnule, and these are frequently so closely folded together, that they appear as if suturally connected. In the Articulata, all arms are composed of single joints, which in

their external form agree with the higher radials, being only narrower, and free plates.

In the Inadunata, in which the arms are free from the first radial, the homologues of the outer primary radials, which we have distinguished as brachials, vary in some genera considerably in number. The greatest variation in this regard occurs among the typical Cyathocrinidæ (Cyathocrinites as we called them heretofore), in which the number varies even among the rays of the same species, so much indeed, that one ray may have one, the adjoining two, the next perhaps five or six. The other groups have rarely more than two brachials, and most of them but one. The brachials are regular arm plates, with a well-developed ambulacral furrow, but without pinnules. The arms are composed of single joints, except in the Poteriocrinidæ and Eucrinidæ, in which the biserial arm structure is associated with the uniserial one. Pinnules are wanting in the Hybocrinidæ, Symbathocrinidæ and Cyathocrinidæ, and in the two former the rays are undivided, consisting of a single arm. In the Heterocrinidæ and Belemnocrinidæ, the pinnules are arranged from every second or third joint throughout the entire arm, the non-arm-bearing joints being united by syzygy, while among the Poteriocrinidæ every joint from the second up, bears a pinnule.

C. *The Interradial, Interaxillary and Interbrachial Plates.*

The interradial plates occupy the intermediate spaces between the primary rays; the interaxillaries between the main divisions of the ray; the interbrachials between the arm bases. All these plates may be considered as parts of the same element. The interradials consist primarily of five single plates, which rest either upon the upper or between the lateral margins of two first radials. Only in the genus *Briarocrinus*, and in a few Ichthyocrinidæ, do the interradials commence higher up. Higher orders of interradials are only found in the Camarata and Articulata. Their office is to increase the capacity of the visceral cavity by incorporating the lower arm-plates into the calyx, and also to strengthen it. They are auxiliary pieces, and serve to fill up spaces, and in this capacity adapt their form to adjoining plates. The higher interradials do not possess the morphological importance of the primary ones, which are early developed in the young individual, and represent important elements throughout the

earlier Crinoids. The interradials increase by age, vary greatly in number, often in the same species, and even in different rays. There are generally two plates in the second row, but sometimes one or three; beyond these the arrangement of the interradials is more or less irregular. In the Inadunata the interradials are located exclusively on the ventral side; in the Camarata both dorsally and ventrally.

The Reteocrinidæ and Acrocrinidæ, exceptionally, possess no primary interradials properly speaking. In the former group, all radials, from the basals up, are separated laterally by numerous minute pieces, without definite arrangement. *Acrocrinus* has a large belt of small plates, separating radials and interradials from the basals, and the interradial series proper commences with two plates.

In Part II, p. 15, when describing the structure of the vault of the "Sphæroidocrinidæ," we discriminated between true interradials and interradial dome plates, the former as being developed around the dorsal, the latter around the ventral pole. At that time we were under the impression, and it was the general opinion among naturalists, that the plates of the ventral side in all Crinoids, recent and fossil, constitute a part of the actinal system. It was known to be the case throughout the Neocrinoidea, and among Palæocrinoids we found several genera in which the interradials of the dorsal side are separated from those of the ventral side. In *Batocrinus*, the higher orders of radials frequently are not separated by interradials, as in the case of the primary ones, but join laterally with their fellows, thereby causing an interruption in the interradial series. These cases, however, form exceptions to the rule; the interradials of the two hemispheres almost always meet each other, and there is no dividing line by which they can be distinguished.

That the abactinal interradials extend to the ventral side, is well shown by the Platycrinidæ and Hexacrinidæ, our former subdivisions Platycrinites and Hexacrinites, in which the first interradials occupy the equatorial zone, and all succeeding ones are located ventrally. When we defined these groups, we described the first row of interradials to be composed of a single plate, a statement which is not strictly correct.

Consulting our figures (Pl. 7, figs. 5–8, and Pl. 9, fig. 6), it will be seen that in the Platycrinidæ and Hexacrinidæ, the first row

of interradials contains not one alone, but invariably three or more plates, placed side by side, all resting upon the upper faces of the first radials. Only the middle plate, the one placed upon the outer ends of two radials, corresponds with the first interradial of other groups; the plates at the sides are accessory pieces, and rank as interradials of the second and third row, respectively. Species with a discoid base have sometimes five plates in the same row, of which only the outer ones meet the second radials. In the simplest form of *Platycrinus*, the middle plate connects directly with the proximals, and at the azygous side with anal plates. In most species, however, the first row is succeeded by other interradials, which either connect laterally with their fellows of adjoining sides, forming with them a continuous belt around the peristome (Pl. 5, fig. 9, and Pl. 7, fig. 6), or are separated by radial structures. In either case there is no dividing line between the plates of the outer and inner rows, and the upper rows always rest against the proximals. The case is the same in *Marsupiocrinus* (Pl. 8, fig. 7), *Hexacrinus*, *Dichocrinus* and *Talarocrinus*, and similar in *Coccocrinus* and *Culicocrinus*, which we shall discuss farther on.

In the organization of the Actinocrinidæ, Melocrinidæ, Eucalyptocrinidæ, Rhodocrinidæ, Glyptasteridæ and Reteocrinidæ, the interradials form even more important parts than in the two groups above mentioned. That here the plates of the ventral side form a continuation of the interradials at the dorsal side, is clearly indicated in genera whose arms are given off in clusters, or in which the rays are formed into lateral extensions. In such species, the interradial series are not disturbed by so many radials, nor by interaxillary plates, and the interradials decrease in size gradually all the way from the first interradial up to the proximals. In species, however, in which the arms are arranged in a continuous ring, the interradials decrease in size more or less from the poles toward the periphery. This decrease in the size of the plates toward the equatorial regions is easily explained by the extravagant increase of arms in those species, and by the nature of the interradial plates, which, as stated, are accessory pieces, filling up spaces. An occasional interruption of the series, therefore, is no proof that the two sections represent different elements.

In some genera the interradials of the ventral side are exceed-

ingly small, without definite arrangement, and they cover the surface radially and interradially. This is frequently the case in the Silurian genera, *Glyptocrinus*, *Periechocrinus*, *Melocrinus* and *Reteocrinus*. Their ventral covering resembles so closely the disk of certain Comatulæ, that it might appear as if this multitude of irregular plates, which sometimes decrease in size toward the periphery, and extend out to the free rays, could not be true vault pieces. In proof, however, that this is the case, we refer to Mr. St. John's carefully prepared diagram of *Glyptocrinus ramulosus* Billings, drawn from a specimen in the Canada Survey Museum, and kindly loaned to us by Prof. Whiteaves. Of the specimen only one-half of the calyx is preserved, and this is imbedded in rock, exposing only the inner floor. *Glyptocrinus ramulosus* is the largest species of the genus, and this facilitates the study of the plates. Like all other species of *Glyptocrinus* it has a large number of irregular interradial, interaxillary and interbrachial plates, which meet laterally over the arm openings, and are continued to the summit, leaving no line of demarkation between the plates of the two hemispheres. In the direction of each arm opening the floor is distinctly grooved, and these grooves or depressions, which diverge from the centre to the arm furrows, evidently lodge the ambulacra. That the grooved plates are not covering pieces, is shown by the fact that they have the same irregular arrangement as the other plates. The whole structure reminds us of *Physetocrinus*, and we have no doubt that the vault in those two genera was built essentially on the same plan. We find this further confirmed by the fact, that in the Canada specimen the inner faces of the interradial and interaxillary plates—but not any of the radial ones—are provided with short nodes, such as are found in many Actinocrinidæ, and which serve there as pillars or partition walls between disk and vault.

In the Crotalocrinidæ, which include *Crotalocrinus* and *Enallocrinus*, the whole ventral surface, in what appear to be the best-preserved specimens, is composed of strong, convex plates, without definite arrangement. In these specimens there is no central piece, nor proximals, nor traces of ambulacra (Icon. Crin. Suec., Pl. 7, fig. 3 *a*; Pl. 8, figs. 6, 7, and Pl. 25, fig. 2); there are, however, other figures of Angelin, apparently of a closely allied species (Ibid., Pl. 17, fig. 3 *a*), in which the plates paving the

ventral surface are much more delicate, and consist of a central plate, large proximals, and several rows of covering pieces, without the intervention of either anambulacral or interradial pieces. It would be difficult with the utmost stretch of our imagination to recognize in the former figures either proximals or central piece, which, as admitted by Carpenter, are present in all these Crinoids, and we think there can be little doubt that the two sets of figures represent different parts of the animal, the one the disk, the other the vault, and that the one covered the other. A similar opinion was evidently entertained by Zittel (Handb. d. Palæont., i, p. 357), who stated that *Crotalocrinus* possessed five "grosse Oralplatten, bald unter der Decke, bald äusserlich sichtbar." According to our interpretation, the calyx of the Crotalocrinidæ extends ventrally to the oral pole, and the ambulacra, central piece and proximals are subtegminal, covered by interradial plates, which extend out to the lower rows of covering plates and side-pieces (Icon. Crin. Suec., Pl. 7, fig. 6, and Pl. 25, fig. 15). A similar condition probably prevailed in the Ichthyocrinidæ, with which the Crotalocrinidæ have close affinities.

In the Ichthyocrinidæ, interradials have been observed only at the dorsal side, where they are subject to many irregularities. In some of the genera they are always present, in others entirely absent; while there are still other genera and certain species, in which they are occasionally undeveloped dorsally. The interradials of the Ichthyocrinidæ are united by ligamentous articulation among themselves, and also laterally with the radials, as shown by the presence of deep fossæ at the sides of the plates (Pl. 5, fig. 5). The mobility in the test, resulting from this structure, led us formerly to state that the ventral covering, which is so rarely preserved, "perhaps" consisted of a "soft or scaly integument." The word "soft" was ill-chosen, and did not express our real meaning, we should have said, as we did in other places, "pliable." There is nothing to indicate a membranous surface structure, but the pavement evidently was pliable in conformity with the condition of the test at the dorsal side. In *Onychocrinus exsculptus*, the only Ichthyocrinoid in which portions of the ventral covering have been observed, Lyon and Casseday found in the radial regions rather large, alternately arranged plates (Amer.

Journ. of Sci., 1859, vol. xxix, p. 79), and in another specimen we found, interradially disposed, small imbricating plates connecting with larger pieces. Whether the latter, as we supposed, represent the summit plates, or Lyon and Casseday's alternating pieces, we could not make out satisfactorily. Carpenter took them to be "covering plates of the ambulacra, which perhaps were permanently closed as in the Platycrinidæ, or only temporarily so as in the Neocrinoids; while the small irregular plates, which form the interradial portions of the vault, correspond to the anambulacral plates of recent Crinoids. They pass downward into the interradials at the sides of the calyx, just as in the recent species and in the Liassic *Extracrinus*" (Chall. Rep., p. 181). We accept the first part of this explanation that these alternate plates probably correspond to the covering pieces of the Platycrinidæ; we even admit these plates to be morphologically identical with those along the disk of the Neocrinoidea. But we doubt if the interradial portions in *Onychocrinus*, or *Platycrinus* either, correspond to the anambulacral plates of recent Crinoids. The interradial plates of vault and disk are very distinct structures; the former constitute a part of the abactinal system, while those of the disk are actinal. Before we enter upon further discussion of this subject, we direct attention to the ventral structure of the Blastoidea and Cyathocrinidæ.

The Cyathocrinidæ were described by us as having no interradials, and until lately we considered this a fixed character of this group. The fact that the only plates interradial in position are located ventrally, seemed to us as sufficient evidence that they were actinal plates, and as such they seemed to be the representatives of the oral plates in the Neocrinoidea. We thought the same regarding the deltoids in the Blastoidea, which occupy essentially the same position in relation to adjacent parts as the above plates in the Cyathocrinidæ. Prof. Zittel, in his "Handbuch der Palæontologie, i," like us, called the plates orals in all three groups, and this interpretation was afterwards accepted by Mr. Etheridge, Jr., and P. Herb. Carpenter, in their paper, "On certain points in the Morphology of the Blastoids" (Ann. Mag. Nat. Hist., April, 1882, p. 214), in which these writers state that in Blastoids the calyx is formed "by

the basals, radials or forked pieces, and the deltoid pieces or orals."[1]

The latter statement seems to us an anomaly. It is impossible that those plates can be orals, and at the same time form part of the calyx. The orals in recent Crinoids have never been considered as calyx pieces, and hence, if the deltoids are orals, they do not belong to the calyx. That, however, they are calyx plates is indicated by their position and relations to other parts, and still more by their enormous variation in size among species of the same genus. If the deltoids were orals, the actinal system in the Blastoids, in forms like *Elæacrinus obovatus*, would occupy over three-fourths of the entire test, while in *Heteroschisma*, which has exceedingly small deltoids, these regions would be reduced to a small circum-oral space. The proportions of the actinal and abactinal regions in the test, respectively, were looked upon by Prof. L. Agassiz as determining the different outlines of the various "orders" of Echinoderms, which he ranked according to the greater preponderance of the one over the other, and this, if true, proves conclusively that the deltoids are not actinal plates, and, therefore, are not orals, but must be interradials. The same argument, however, cannot be applied to the Cyathocrinidæ, in which the so-called orals are located ventrally, and from analogy with recent Crinoids should be actinal plates.

By carefully removing the arms in some of our best specimens of *Cyathocrinus*, we succeeded in exposing the ventral surface in several species, and were enabled to observe its structure in various stages of preservation. In a specimen of *Cyathocrinus Gilesi* (Pl. 4, fig. 2), from the Burlington and Keokuk Transition beds, we found *in situ* the five large interradial plates, the so-called orals, all connected laterally, and each one provided along its upper face with a conspicuous central node. In another specimen of the same species (Pl. 4, fig. 3), these interradials were partly covered along their surface by numerous irregular pieces, but so as to leave the central node exposed, the face at a level with the small tegminal pieces. In two specimens of

[1] We are pleased to state that Dr. P. H. Carpenter, whom we had acquainted with the modification of our views regarding these plates, now fully agrees with us that neither those of the Blastoidea nor Cyathocrinidæ are orals (see Chall. Rep., p. 162).

Cyathocrinus multiradiatus from Crawfordsville, of which the one is figured (Pl. 4, fig. 6), the entire surface of the interradials, and also the circum-oral space, is covered by minute plates, except at one end (see figure) where the plate underneath is exposed to view. The structure is similar in *Cyathocrinus iowensis* from the Lower Burlington limestone (Pl. 5, fig. 7), but there the plates closing the peristome consist of eight considerably larger pieces, placed around a central one, arranged in pairs, of which each pair corresponds in form and position to one of the four large proximals in other genera.

In the above specimens, the so-called orals are covered along their sutures by well-defined ambulacra, lined by side-pieces and covering plates, and these connect laterally with the small tegminal plates which we have described. That all surface plates in these species are perisomic, nobody will doubt after consulting our figures, and that the plates supporting them are interradials and not orals, is proved by the fact that they surround the peristome, but do not cover it, and are succeeded by numerous other plates.

This, however, was not the structure of the Inadunata generally, or even of all Cyathocrinidæ. Angelin figures from the Silurian of Sweden (Icon. Crin. Suec., Pl. 23, figs. 10 *b*, 11), two specimens under the name of *Cyathocrinus alutaceus*, in which the interradials (orals) were exposed, and not covered by plates. They have a central piece, surrounded by four large proximals, and there are, alternating with them, five conspicuous radial dome plates, with numerous irregular pieces along the posterior or anal side, which join the central plate, and extend outwards, forming a short protuberance, composed of small pieces. There are at the surface no traces of ambulacra, and the whole structure ventrally is almost identical with that of certain forms of *Platycrinus;* while the dorsal side of the species shows clearly the charàcters not only of the Cyathocrinidæ generally, but the detail structure of the genus *Cyathocrinus*. The total absence of ambulacra upon the surface proves that in this species the disk was subtegminal, covered by the plates which have been heretofore called orals, but which are identical with the first interradial plates of *Platycrinus*, and with the first interradials of *Actinocrinus* and other Camarata. The structural identity with all these plates proves that the interradials of the Cyathocrinidæ, and the deltoids of the Blastoidea,

are abactinal plates, that they constitute a part of the calyx; and it proves further, which is equally important, that some of the Palæocrinidæ have abactinal plates along their ventral side. That *C. alutaceus* cannot be retained in the same genus with the Carboniferous forms is self-evident. The two are morphologically in a very different condition, and we should propose for the former a new generic name if we had before us specimens in place of figures.

Carpenter fully accepts the views previously held by us, that in the Camarata all interradials located dorsally are abactinal plates, and those at the ventral side actinal. It should be stated, however, that we had communicated to him, in time for the Challenger Report, the modifications our views had undergone on this point. We make this statement to show that Carpenter's interpretation of the plates was not based upon our—as we believe—erroneous observations, but was the result of his own studies. Carpenter even goes further than we ever did. He asserts that the plates, which we took to be the actinal representatives of the interradials, in some groups, are anambulacral plates, and form a part of the disk.

His interpretations of the interradials in the Platycrinidæ are not always harmonious. If we understand him correctly, he regards the first interradial piece as a calyx plate (Chall. Rep., p. 40), but all succeeding ones as perisomic, "much more substantial, however, than in Neocrinoids, and forming part of the solid covering, but not a true vault or *tegmen calicis*" (Chall. Rep., p. 179). On the same page he states further: "Although believing that the vault of a Platycrinoid corresponds collectively to the orals, interradials, ambulacral and anambulacral plates of Neocrinoids, I do not wish to assert that the Platycrinidæ either had an external mouth or open ambulacra on the disk." On page 178, however, he states that the "series of four or six interradials, corresponds generally to the single large interradial of *Cyathocrinus*." It is not clear to us, how the same pieces can be anambulacral, *i. e.* disk plates, and at the same time "correspond generally" to a true interradial plate. He supports his theory by pointing to the alternating pieces, the so-called "covering plates," which in most of the Platycrinidæ appear along the radial portions of the ventral surface, and which he believes are always subtegminal in *Actinocrinus*. He says: "I do not myself think

that the vault of a Platycrinite was exactly of the same nature as that of an Actinocrinite, *i. e.*, that it covered in the whole of the visceral mass and ambulacra on its upper surface. For if the alternating dome plates represent the covering plates of recent Crinoids, then all the periphery of the dome, outside of the apical dome plates, must be the real ventral surface of the body, and not a *tegmen calicis* as in *Actinocrinus*." And he states further, on page 179: "There is some point on the actinal side of every Crinoid where the food grooves leave the oral system, covering up the peristome in which they originate, and are only closed by the covering plates at their sides." This is quite true as to the Neocrinoidea, in which the calyx is limited to the dorsal side, but not altogether in the case of the older Crinoids, in which the calyx, as we believe, takes up the greater part of the ventral surface, and the covering pieces frequently are embodied among abactinal plates. In the Platycrinidæ the disk is subtegminal, although portions of the covering pieces appear along the surface, but these, in place of lining the sides of the food grooves, are incorporated between the interradials, resting between them as solidly as the summit plates, and cover the food grooves as tightly, as the interradials do in *Actinocrinus*.

Carpenter agrees with us that the radials above the first are fundamentally arm plates, which, in the growing Crinoid, by the increase of interradials, were incorporated into the calyx. During the process of incorporation, by the widening of the equatorial zone, the ambulacral vessels and food grooves of the incorporated arm plates, gradually were lifted out from the arm-furrows, and stretched out along the disk in the form of tubes, being enclosed from above and below by plates. These ambulacral tubes in most of the Actinocrinidæ are altogether subtegminal, and located at a distance from the inner floor of the vault, until on approaching the arm bases they not only come in contact with, but raise up the interradial plates and push them aside, exposing to view the upper rows of tube plates, the so-called covering pieces, which are thence continued along the arm furrows.

In the Platycrinidæ, the conditions are essentially the same as in the Actinocrinidæ, but most generally the covering-plates of the tubes penetrate the vault before they pass into the arms. This takes place either along the outer edges of the proximals,

or beyond the succeeding ring of interradials. In either case, however, the covering-plates join laterally with the interradials, and accommodate themselves, more or less, in form and size, to the surrounding plates, so much, indeed, that frequently they attain the same rigid form as the true vault pieces (Pl. 7, figs. 5, 7, 8). Sometimes, however, as in the case of *Marsupiocrinus cœlatus*, the alternating plates retain their original form and delicate structure, while in the same genus, in *Marsupiocrinus Tennesseæ* (Pl. 8, fig. 7), they are as rigid as the interradials.

For proof that our descriptions of the alternating plates, and the ambulacral tubes generally, are based upon actual observation, we refer to the casts of *Dorycrinus* (?) (Pl. 4, fig. 5), *Strotocrinus* (Pl. 4, fig. 4), and *Platycrinus* (Pl. 5, fig. 9), in all of which the ambulacra, at some distance before entering the peristome, are covered up in the cast and are visible upon the surface only at or near the arm bases. The cast of *Platycrinus*, which we have illustrated, shows beautifully the alternate arrangement of the covering plates, which pass out from beneath a belt of large interradials. Looking at this figure we do not see how Carpenter can any longer maintain that *Platycrinus* possessed no tubular skeleton, and that the upper interradials are anambulacral plates. The specimen will also convince him that there are in this genus upon the surface of the cast no " elevated rounded ridges, almost like strings overlying the surface," as he imagined (Chall. Rep., p. 179), and which, he thought, represented " the open food grooves of recent Crinoids." Among the twelve or more casts of *Platycrinus* which we examined from Mr. Rowley's collection, not one bears that string-like structure, and in all of them the ambulacral tubes are placed around the peristome at a distance from the vault. That even in the Actinocrinidæ those strings which we noticed upon the casts do not represent organs connected with the food grooves, will be shown elsewhere.

Among Actinocrinidæ, and probably in other families, the covering plates sometimes penetrate the interradials in a similar manner as in the Platycrinidæ, and this is so even in the genus *Actinocrinus*. *Actinocrinus stellaris*, from the Mountain limestone of Belgium, has a row of alternating plates covering the food grooves, a character not well shown in De Koninck's figures; although the arrangement of the plates is very regular in the specimens, and almost identical with that of certain species of

Platycrinus. They form a ridge of strong tuberculous plates, and are almost as prominent as the apical or summit plates of this species, while the interradials, from the first to the last, are scarcely convex. The same structure is also found in *Stegano-crinus concinnus* (Pl. 8, fig. 4). In *Carpocrinus ornatus*, however, the alternate plates retain, more or less, the character of other perisomic pieces.

Wherever covering plates in the Camarata are exposed, they are invariably placed on a level with the interradials, not upon their surface, and the ambulacra are essentially in the same condition as those of the Actinocrinidæ, only the interradials do not close over them, but are pushed aside. The case, however, is very different in the higher form of *Cyathocrinus*, in which not the covering plates alone, but the whole tubular skeleton and the entire disk is exposed.

The discovery of anambulacral plates upon the surface of the interradials is morphologically of the utmost importance, as throwing light upon the phylogenetic as well as the ontogenetic development of the older Crinoids and their relation to the Neocrinoidea. If a resorption of these interradial plates, as we believe, took place in the Poteriocrinidæ, then the dividing line between the older and later Crinoids becomes so narrow, that it is difficult to decide where the one terminates and the other begins. A resorption of the interradial plates in palæontological times is in accordance with the embryological development of recent Crinoids. Carpenter is inclined to believe (Chall. Rep., p. 40), that the interradial plates, which Sir Wyville Thomson (Philos. Trans., 1865, p. 540) observed in the early larval stages of *Antedon rosacea*, and which he takes to be primary interradials, "eventually undergo resorption like the orals and the anal plate."

In the Neocrinoidea, with the exception of *Thaumatocrinus*, *Guettardicrinus*, and one or two species of *Apiocrinus*, the interradials are represented by indistinct plates, and are only temporarily developed. In the Palæocrinoidea, however, the interradials are permanent, and in some groups so extravagantly developed that they constitute the greater part of the calyx. It is very remarkable that we find the most profuse development of interradials among Silurian genera, which tends to prove that a largely developed interradial system represents a lower grade

of organization in these Crinoids, especially as these plates increase numerically in the individual by growth. In the Crotalocrinidæ they cover the entire peristome, including the central piece and proximals. In the Reteocrinidæ and Glyptocrinidæ they extend from the basals to the central piece. In *Actinocrinus*, *Melocrinus* and *Platycrinus*, from the first radial to the proximals, exactly as in the early *Cyathocrinus*, only that in the latter the interradials consist of a large single plate, in the others of numerous small ones.

If it were true that the deltoids of the Blastoidea, and their representatives, the interradials of the Cyathocrinidæ, were orals, the first interradials of all Camarata would be oral plates, and all higher orders upward growth of the orals. That this is not the case is clearly shown by the fact that all these plates, from the first to the last, are calyx plates, *i. e.*, abactinal; while the orals of the Neocrinoidea are actinal, being developed around the left peritoneal tube.

That the interradials and their associates, the interaxillaries and interbrachials, dorsally and ventrally, are abactinal plates is further shown by the presence of perisomic plates underneath the vault, which, wherever they have been observed subtegminally, extend from the first interradial to the end of the central piece (Pl. 2, fig. 8). The disk of the Palæocrinoidæ, therefore, begins from beneath the first interradial, and rests, as in the Neocrinoidea, against the first primary radial, thereby making the first interradial, in the true sense of the word, a vault plate.[1]

According to Carpenter, the Ichthyocrinidæ and some of the doubtful Silurian forms, such as *Reteocrinus* and *Xenocrinus*,

---

[1] The term "vault" has been heretofore applied by most writers to all plates of the ventral side. In this sense it is actually a misnomer. If the term is used at all, it should by right include all interradial, interaxillary and interbrachial plates, dorsally and ventrally, and these might be very appropriately designated as vault plates, to distinguish them from the perisomic or disk plates, which are placed beneath the others, and follow their direction. But fearing that the introduction of a new term, or giving a different interpretation to the same term, might produce confusion, we retain it as a convenient and short mode of expression for all plates of the ventral side that are not perisomic. It is therefore a merely conventional term. Carpenter applies it to all actinal plates of the dome, with the exception of the perisomic ones, in which he includes all interradials of the ventral side which he takes to be actinal.

appear to occupy an intermediate position between the heavily vaulted Platycrinidæ and the more thinly plated recent forms.

We have shown already that neither the small irregular plates in *Glyptocrinus*, nor any of the interradials of *Platycrinus*, are perisomic plates, and this in itself is a strong proof, that the structure, which occupies relatively the same position in the allied genus *Reteocrinus*, cannot represent a totally different thing. Carpenter leaves us in doubt whether the so-called disk of *Reteocrinus* and *Xenocrinus* begins at the basals, where those minute irregular pieces commence, or at the equatorial zone, as he believes it does in *Glyptocrinus*. It seems to us, if he had not meant the whole interradial series, he would not have made a comparison of these parts with those of the Liassic *Extracrinus* and recent forms without interradials, but would rather have selected *Thaumatocrinus*, in which interradials are present. He also indicates it by his remarks on the fixed pinnules of *Reteocrinus*, which, as we know, are located dorsally, and which he says (Chall. Rep., pp. 39, 40) are soldered together by the minute irregular plates, which pass insensibly upwards into the plates of the so-called vault, and further: "This condition recurs constantly in the Liassic *Extracrinus*, and in the recent Pentacrinidæ and Comatulæ; and I see no reason to believe that the minute interradials of *Reteocrinus* are in any way different from those of the Neocrinoids. But I regard them as perisomic plates, continuous with those of the disk above, which was in no sense a vault like that of the Actinocrinidæ."

According to this, if we understand him correctly, the calyx in the Reteocrinidæ consisted only of basals, underbasals and radials, which latter throughout their full length were enclosed by perisomic plates. This would be a very peculiar condition for one of the earliest known Crinoids, if we admit that the Palæocrinoids are developed from a lower morphological level than the Neocrinoidea. In support of it Carpenter has no other proof than a superficial resemblance in the form of the plates. There is nothing to show that any of the plates were perforated, there is no external mouth, no food grooves, nor plates that could possibly be considered as covering pieces. All the plates dorsally and ventrally, even those extending to the free rays, have the same irregular arrangement. The ventral surface of *Reteocrinus* is almost identical with that of *Glyptocrinus decadactylus*, which

S. A. Miller (Cincin. Soc. Nat. Hist., Dec., 1883), decribes as follows: "It is composed of numerous polygonal plates. Those in the central part are the larger ones, and each of these bears a central tubercle, which is sometimes prolonged so as to be designated a spine. Toward the margin, or rather following the undulations toward the intertertiary areas, the plates are smaller and possessed of slight convexity. They unite in the depressions in the intertertiary areas with the plates of the calyx, or rather the interprimary radials graduate through the intersecondaries and intertertiaries to the plates of the vault without any line of separation. The plates become smaller as they approach the inner face of the arms, over the swelling undulations of the vault, and continuing to decrease in size, form a somewhat granular, continuous integument, that covers the ambulacral furrows. This continuation of the vault up the inner side of the arms, has been observed for a distance of an inch above the vault, and, no doubt, extended as far as the arm furrow itself."

We have carefully examined Miller's original in Dr. R. M. Byrne's collection, and can attest the correctness of his description. The decrease in the size of the plates toward the periphery, which evidently led Carpenter to consider those plates as an outgrowth from the oral side, is readily explained by the enormous accumulation of plates from the interradial, interaxillary and interbrachial series, which terminate soon after entering the ventral side, or else diminish in width. That the vault in *Glyptocrinus* and *Reteocrinus* extends over the full length of the arms, as suggested by Miller, and that only their large pinnules had open food grooves, is at least doubtful, although it may be possible, as such is the case in the allied genus *Melocrinus*, in which, however, the pinnule-like arms are provided with extra pinnules.

Carpenter attaches considerable importance to our incidental remark, "that the peculiar depressed state of the interradial and interaxillary areas of *Reteocrinus*, the irregularity in the arrangement of their plates, suggests the possibility that those parts were adapted to expansion by the animal." And he makes use of this as an argument in favor of his theory that the ventral plates of *Reteocrinus*, like those of the Ichthyocrinidæ, represent "the plated perisome of the Neocrinoids." That the test of *Reteocrinus* was in any way pliable, has been given up by us entirely, nor do we believe that the pliable test of the Ichthyo-

crinidæ bore any relation to the disk of recent Crinoids, but we believe, as strongly as ever, that their ventral surface was covered by a vault. A vault paved by small irregular pieces, and folded like the disk of recent Crinoids, with elevations following the food grooves, is found not only in *Glyptocrinus* and *Reteocrinus*, but also among the later Actinocrinidæ. The surface elevations, which form natural grooves at the inner floor, represent more or less open galleries, which in other forms are produced by a thickening of the plates along the inner floor. Miller's description of the vault of *Glyptocrinus* would apply equally well to *Physetocrinus reticulatus* which, as we know from actual observation, has a vault and a well-developed disk underneath. An open disk represents a higher form in the developmental history of the Crinoids, than a closed one. This is shown by *Cyathocrinus*, in which the vault is gradually replaced by the disk, and it is very improbable that the Reteocrinidæ, which did not survive the Lower Silurian age, attained a higher organization than most of the Carboniferous Actinocrinidæ.

According to Carpenter (Chall. Rep., p. 172), "the vault of *Actinocrinus* has been developed on the left larval antimer, in exactly the same way as the apical or abactinal system is developed on the right; but the oral system, instead of being limited to five oral plates, as in Neocrinoids, reached a very extensive development, so that in its completest form it represents such a parallel to the apical or abactinal system as is to be met with in no other Crinoid." A similar view was expressed by us when we wrote Part II of this Revision, but we believe the same thing might be said of other Actinocrinidæ and all Platycrinidæ and Rhodocrinidæ.

Carpenter, as we have stated, applies the term "vault" to all actinal plates covering the disk and tentacular vestibule, and in most of the Actinocrinidæ he regards all interradial plates of the ventral side as the representatives of the interradials at the dorsal side. However, in a few Actinocrinidæ and in the Platycrinidæ, Rhodocrinidæ and allied groups, he restricts the vault to the central piece, proximals and radial dome plates if such are present, and all other ventral plates he takes to be perisomic. In the Cyathocrinidæ and Blastoidea he limits the vault to the summit plates; but their interradials, although located ventrally, are said to be abactinal. These interpretations, if correct, would

suggest, either that the condition of the ventral surface is of comparatively little value for classificatory purposes, or that certain forms, which have heretofore been described under *Actinocrinus*, are structurally very different, and should be referred to remote groups. It would further prove, if the upper interradial plates in *Platycrinus* were anambulacral pieces—because some of the covering pieces are interposed between them—that the higher interradials of *Actinocrinus stellatus*, which are in the same condition, are perisomic, and *vice versa* those of certain Platycrinidæ vault plates; indeed, that the very same plates which in the young Platycrinoid represent vault pieces, are perisomic in the adult.

Carpenter will admit that the minute temporary interradials, which Sir Wyville Thomson observed in the larva of *Antedon*, are the homologues of the large and permanent calyx interradials in the Cyathocrinidæ. In this group, in which the rays are free from the first radial, the interradials, for want of any other lateral support, join with each other, and thereby attain their ventral position; while in the adult Actinocrinidæ and Rhodocrinidæ, which have numerous radial and interradial plates, the first interradials naturally had to be located dorsally. The increase of interradial plates took place gradually in the growing animal, and from that we may reasonably suggest that these Crinoids at one time in their larval state possessed but five single interradials, which met over the disk ventrally, as in the case of *Cyathocrinus alutaceus*. At that time the young *Actinocrinus* was essentially in the condition of a young *Antedon* in which the interradials had made their appearance, however the interradials of the Palæocrinoid were more fully developed. If now *Allagecrinus* and *Haplocrinus*, as suggested by Carpenter, represent palæontologically a very early stage of the larva of *Antedon*, we should like to know something about the condition of the interradial plates in those genera. Are they as yet contrary to all other Palæocrinoidea altogether unrepresented, or here already resorbed by the animal? Both genera have five plates, which occupy the very same position as the interradials of *Cyathocrinus alutaceus*, and *Cyathocrinus Gilesi* (Pl. 4, fig. 2). Why should these be orals, when there is another structure covering the tentacular vestibule, which may represent them, and which, on the other hand, would be totally unrepresented in the *Antedon* larva and in all other Echinoderms?

The phylogenetic evidence indicates clearly that the interradial element takes a most prominent part in the composition of the Palæocrinoidea, and we hope we have proved that these plates were much more extravagantly developed in their earlier types. In Silurian genera they extended over the whole peristome, or the greater part of it. Gradually the summit plates made their appearance, evidently pushed out from beneath, afterwards the covering pieces of the ambulacra, and at last also the anambulacral plates. Even in the Cyathocrinidæ, in which the ventral structure attained a higher form than in any other group, with the exception, perhaps, of the Poteriocrinidæ and Encrinidæ, interradials are not only present, but they occupy the greater portion of the ventral side, and even in those genera in which, perhaps, they were resorbed before the Crinoid reached maturity, they had been previously well developed. Under the weight of this evidence, is it probable that *Haplocrinus* and *Allagecrinus*, which are said to be "permanently in the condition of a very early larva" (Chall. Rep., p. 157), alone among all Palæocrinoidea, should have no interradial plates, and that the plates which occupy their position in these two genera are "oral plates?" We, at least, wish to be excused if we doubt it. Upon palæontological grounds we expect to find in the younger stages of the Palæocrinoid the oral system feebly, the interradial system extravagantly developed, while, according to Carpenter's interpretation of the plates, in the Palæocrinoid larva, the entire ventral surface from the radials up would be oral, *i. e*, actinal.

From an embryological standpoint also, Carpenter's interpretation meets with very serious objections. If *Haplocrinus* represents, as he asserts, a very early stage in Crinoid ontogeny, before the opening of the tentacular vestibule to the exterior, we should like to know how the central piece, the so-called orocentral of Carpenter, made its appearance in the Palæocrinoid. It is not very probable that this plate was present in the early larva, or it would certainly be represented in the larva of the Neocrinoid at the time the oral pyramid was closed. Carpenter claims that it was even unrepresented in *Allagecrinus*, and that the oral pole was closed only by oral plates. This would suggest that it was introduced either by means of a partial resorption of the "oral" pyramid, or by the opening of its plates. The former is exceedingly doubtful, while the latter is clearly not the case in

Haplocrinus nor other Palæocrinoidea, for the proximals which Carpenter takes to be the representatives of the orals, are permanently closed, with the exception of *Coccocrinus*, in which the "orals" are said to be parted, but in which the central plate is wanting.

Another difficulty is offered by the fact that the so-called "oral" plates are pierced by the anal opening, a structure which certainly has no parallel among recent Crinoids.

Allagecrinus was described by Etheridge and Carpenter (Ann. and Mag. Nat. Hist., April, 1881) as without central piece, and the latter has since informed us, that he could not identify any such plate on re-examining the specimens. This, however, does not prove that it was wanting, for we must bear in mind that *Allagecrinus Austinii* is an almost microscopic form, not larger than a coarse grain of sand. The central piece was overlooked by the European naturalists, in the much larger *Haplocrinus*. Goldfuss, however, observed in (*Eugeniacrinites*) *Haplocrinus mespiliformis* (Petref. Germ., i, p. 214) "ein rundes Knöpfchen im Scheitelpunkt," and it is very significant that Etheridge and Carpenter also found in *Allagecrinus* "at the central end of one or more of the plates faint tubercles," for which, according to their own statement, "they can find no explanation." Whether these represent the tubercles which we discovered upon the face of the interradials in *Cyathocrinus multiradiatus* (Pl. 4, fig. 2), we are of course not prepared to assert with certainty, but it is worthy of note that Carpenter regards the latter "as the conical openings in *Granatocrinus Norwordi*,"[1] and it is very possible that they are the same thing in all three groups, which would prove better than anything else, that the plates bearing them are not orals but interradials. The tubercles in *Allagecrinus* (compare Ann. and Mag., ser. 5, vol. 7, Pl. xvi, figs. 3 *b*, 4, 5 and 7 *b*), are evidently of structural value, but as there is but one figured, although the description speaks of one to each plate, and this is located laterally in one specimen and centrally in the other, all interpretations by us must necessarily be more or less problematical. We are inclined, however, to believe that the lateral one (fig. 5), in analogy with *Haplocrinus*, represents the anal opening, *i. e.*

[1] This suggestion was made by Dr. P. Herb. Carpenter in his letter of December 26, after sending him our figures, and he kindly permitted us to make use of it in our writings.

the larger tubercle in *Granatocrinus*, and the central one, if it exists at all, the central piece; but whether this plate is exposed or not, we believe it was represented in the Crinoid, and if it was not inserted between the interradials, it was subtegminal, underneath them.

In the later stages of *Allagecrinus*, according to Carpenter and Etheridge (p. 285), the so-called "orals" are placed "at the centre of the dome, in close contact laterally, so that no opening is visible, but their basal angles are more or less truncated, leaving a superficial gap between every pair of plates, which corresponds in position with the articular facet on the subjacent radial." "The interior of this gap, however, is filled up by the deeper portion of the oral plates." This structure, we admit, indicates that possibly at a more advanced stage of the Crinoid, the plates had separated laterally, similar to the orals in the recent *Holopus*. This, however, which we believe was really the case in *Coccocrinus*, does not prove that the plates of the two groups are homologous, as similar modifications take place among the interradials in the Palæocrinoidea, or as we should say, take place in the earlier Crinoids exclusively in the interradials, while the tentacular vestibule remains perfectly closed. In the case of *Allagecrinus*, the opening out of the plates toward the arm bases, indicates, in our opinion, that the Crinoid is approaching the stage of a Platycrinoid, in which the covering plates part the interradials and enter the vault; previous to the later Cyathocrinoid stage, in which the whole ambulacral skeleton covers the interradials. *Coccocrinus* represents a transition form between the two former, the interradials being separated from one another, forming open clefts with the ambulacra at their bottom.

The ventral side of *Coccocrinus rosaceus* in the best-preserved specimens consists of ten plates, all strictly interradial in position, arranged in five series, which are not in contact laterally nor centrally, leaving five rather conspicuous clefts and a central opening. The outer plate of each series is smaller, the inner resting upon the truncate face of the other. The inner plate at the azygous side is larger, and the anal opening excavated along the suture between the two plates, extending as deeply into the inner as into the outer plate. There are no special anal pieces, neither dorsally nor ventrally.

There is no difference of opinion as to the outer plates, which

all recognize as interradials; the inner ones, however, were designated by Roemer as "kleine interradiale Stücke, welche von dem Mittelpunkte der Scheitelfläche zu den Armen verlaufen." Schultze called them "Scheitelstücke," Zittel and De Loriol "orals," and all speak of open ambulacral furrows leading to the arms, and of an external mouth. The latter two writers refer the genus to the Haplocrinidæ, Schultze to the Platycrinidæ. Carpenter (Chall. Rep., p. 163), regards *Coccocrinus*, "like the recent *Holopus*, to be permanently in the condition of a Crinoid larva in which the orals have not yet moved away from the radials, though separated from one another." In the interpretation of the plates he agrees with Zittel, De Loriol and Allman.

A similar interpretation was given by us in our generic description in Part II, when we took the plates of the inner ring to be identical with the so-called "orals" of *Cyathocrinus*, but this has been abandoned after finding the latter plates to be interradials, and they are now regarded by us as secondary interradial plates. When we adopted Zittel's interpretation, we were misled by the superficial resemblance to the oral pieces in the recent genus *Hyocrinus*, overlooking the fact that the latter rest within a belt of perisomic pieces, in place of interradials in the former. *Coccocrinus bacca*, as seen by Roemer's figure (Fauna West. Tenn., Pl. 4, fig. 5 *c*), has three interradials arranged transversely as in the Platycrinidæ, the outer ones resting against the secondary radials. The presence of higher interradials in this species is sufficient to prove satisfactorily that the genus *Coccocrinus* is no Haplocrinite, and that it does not even go with the Inadunata. It is possible that *Coccocrinus rosaceus* had exceptionally but one interradial within the first row, but as a member of the Camarata it must have possessed higher interradials, like other Palæocrinoids in which the interradials come in contact with the higher radials, contrary to the Inadunata, which have, as a rule, a single interradial plate.

We doubt if even Carpenter, although he is inclined to accept the upper series of interradials in *Platycrinus* as anambulacral plates, will go so far after examining our diagrams, as to include among these the lateral plates of the proximal row, either in *Platycrinus* or *Coccocrinus*, which he overlooked in both genera. *Coccocrinus* is certainly not in the same morphological condition as *Holopus*, even admitting, which we do not, that the upper

interradial plates were orals. In the latter genus, the orals rest against the radials, and the ambulacra are exposed only along the arms. In *Coccocrinus*, however, the so-called " orals " abut with their outer ends against the interradials, and the clefts from the " orals," in place of entering the arms, are continued between the interradial plates.

In Part II, p. 58, we asserted that the clefts along both plates were probably filled in the animal by alternate (covering) pieces, and the summit openings by dome plates; although regarding at that time the inner circlet of interradials as oral pieces. We admit that Carpenter is right in asserting that the existence of covering plates between the orals is contrary to the structure of recent Crinoids, and at variance with the nature of oral plates generally; but considering, as we do now, that the inner as well as the outer plates are interradials, this objection loses its force, since covering plates are found between interradials in most of the Platycrinidæ. Yet the case of *Coccocrinus* is somewhat different from that of an ordinary Platycrinoid, which together with covering pieces has well-developed summit plates, of which no trace has been found in any of the specimens of *Coccocrinus*. Carpenter thinks that in *Coccocrinus* the central piece was unrepresented, that its *five* inner interradials are homologous with the *six* proximals of *Platycrinus*, and that the tentacular vestibule with the mouth at the bottom was exposed to view. This interpretation is a natural consequence of his oral theory, and shows still more forcibly the difficulties of his position. Not only has he to admit a homology of five plates to six, but that in a Silurian genus mouth and food grooves were not covered. This assumption, which represents an enormous advance in the development of the group, not attained by any other Palæocrinoid, is alone sufficient to overthrow his whole theory, and this the more when applied to a genus which decidedly represents a low stage among these Crinoids. What is left to make *Coccocrinus* a Palæocrinoid? Even the asymmetry, which, according to Carpenter, is one of the best characters for separating the older and later Crinoids, is rather problematical, as it has no special anal plate.

Admitting that the inner plates in *Coccocrinus* are secondary interradials and not proximals, we have to account for the absence of these plates in this case. That the summit plates, which

are so universally represented throughout this group, should be totally absent in this genus, seems to us not very probable. Yet the central opening which should contain them is so small, compared with the space taken up by them in *Platycrinus* and allied forms, that it seems almost impossible to have been occupied by seven or more plates. Besides, there is not a single instance known to us, in which either the summit plates or the covering pieces were obliterated in the specimen, leaving at the same time the interradials in position, as we find it in all these specimens. This leads us to the conclusion that in *Coccocrinus*, as in *Platycrinus*, the five interradial series had been separated laterally to their full length, but that the disk covered by the summit plates had not been raised to the surface as in that genus, leaving an open gap and lateral clefts permanently as in *Holopus*, with the exception, however, that in the latter genus the clefts are formed between the orals. According to our interpretation, *Coccocrinus* represents phylogenetically a transition form between *Culicocrinus*, in which the interradials are still closed and its summit plates and covering pieces subtegminal, and *Platycrinus* in which they are incorporated with the calyx. This is the only explanation which meets all difficulties, and brings these genera, with regard to the distribution of the plates, under the same rule with the other Palæocrinoids.

The genus *Symbathocrinus* is morphologically a much higher form than either *Coccocrinus* or *Haplocrinus*, not only because it had better developed arms, but also well developed summit plates. Its summit had never been observed until we removed the arms in very perfect specimens, and succeeded in laying bare the whole ventral surface. It consists of eight plates, four large proximals, which, together with three other plates, along the azygous side, form a closed ring around a very conspicuous central piece, and these again are enclosed by ten or more smaller pieces, which rest upon the highly elevated articular facets of the radials.

These outer plates (there may be one or two additional ones toward the azygous side) are smaller than the proximals; five of them are placed radially, the others interradially. In the first specimen which we dissected, and which was sent to Dr. Carpenter for study, the lateral sutures between the smaller plates could not be distinguished. That plates were interposed between the radials

and proximals (his orals) was clearly shown, and was also noticed by him in his letter. We were, therefore, somewhat surprised when we found them ignored in his discussion, and observed his statement that " the so-called apical dome plates rest directly upon the upper edges of the articular faces." We regret this the more, as we should like to know whether he regards them as calyx or perisomic plates. In our opinion they cannot be perisomic, as five of them have a strictly radial position. Nor do we believe that the five radial openings which we at first thought we observed along the upper angle of these plates, at their juncture with the proximals, are ambulacral or arm openings, as Carpenter suggests. We are inclined to take them for mere depressions along the suture, as it is very improbable that the ambulacra in proceeding to the arms passed over these plates. We regard the five radial pieces as radial dome plates, and the alternate ones as interradials. Carpenter also omits to state whether the " orals " in *Symbathocrinus* consist of five or six pieces. That there are more than five is clearly seen in the specimen which he examined, although the exact number could not be ascertained. Other specimens, however, which we have since prepared (Pl. 4, figs. 9, 10), prove clearly that there are seven pieces. This is morphologically of the utmost importance, as showing that the summit structure of *Symbathocrinus* is altogether different from that of *Haplocrinus* or *Rhizocrinus*, with which Carpenter identifies it, and it is more like that of *Platycrinus*. We shall return to this when we take up the oral plates.

As a result of the foregoing observations, we draw the following conclusions, viz.:—

1. Interradials are represented in all groups of the Palæocrinoidea. They were early developed in the larva, attained at once large proportions, and persisted through life or were resorbed on approaching maturity.

2. They extend invariably to the proximals, or even cover them completely.

3. They are more extravagantly developed in the earlier groups, not always in number, but by extending over comparatively larger space.

4. In all groups in which the arms are free from the first radials, they are represented by only five single plates, and these are located ventrally. Groups with two or more radials have

two at least, and the number increases in proportion to the increase of the radials, by means of which the lower series attain gradually a dorsal position.

D. *The Anal Plates and Anal Tube.*

It has been a general practice to regard all plates of the azygous interradius as anal plates. From a strictly morphological standpoint this is not correct, as comparatively few of these plates are connected with the anal aperture, although all of them are more or less affected by it. Properly speaking, in analogy with recent Crinoids there is but one true anal plate, and the succeeding pieces are either interradials, or they constitute parts of the anal tube, which, in the growing animal, by the increase of interradials, were incorporated into the test. The latter plates, as representing parts of the calyx, which serve the same purpose as the true anal piece, might be very appropriately distinguished as "higher" anal plates, but unfortunately in many groups it is almost impossible to separate them from the interradials. A discrimination, however, should be made wherever it is practicable.

In the Pentacrinoid larva of *Antedon rosacea*, according to Dr. W. B. Carpenter (Philos. Trans. Royal Soc. London, pp. 726–747), the anal plate makes its appearance almost contemporaneously with the first radials, and stands on a level with them. It is at first a rather irregular plate, which somewhat later takes an elliptic form, and is gradually lifted out from between the radials, and developed into a conspicuous funnel, which disappears at the end of Pentacrinoid life, being removed by resorption.

The earlier stages of the anal plates in the Palæocrinoidea are only known from phylogenetic evidence, but this shows that the modifications which they undergo in palæontological times correspond closely with those of the growing Pentacrinoid. In the Inadunata, which have closer analogies with the Neocrinoidea than the other two groups, and which like them have but a single anal plate, the latter can be traced from its first appearance in the Silurian to its total resorption in the Carboniferous and Trias, and the various conditions of development, as thus represented, form excellent characters for generic distinction. Among the earliest Inadunata, however, we find a transition state which either is unrepresented, or has not been recognized in the Penta-

crinoid. We refer to the development of the anal plate from the so-called azygous piece. That a plate which takes such an important part in the phylogeny of this group should be altogether unrepresented in the young Neocrinoid, seems to us somewhat doubtful, the more so as the Neocrinoidea are in all probability the palæontological successors, if not the linear descendants, of the Inadunata. Possibly the undivided azygous plate, as represented in *Baerocrinus*, has been overlooked in the early larva, and this would not be surprising, as the plate occupies the position, and has very nearly the form of an ordinary first radial.

In our chapter on the radials we have already alluded to the azygous piece, and expressed our conviction that its gradual resorption gave origin, not only to the right posterior radial, but also to the anal plate. We have shown that in *Haplocrinus*, a close ally of *Baerocrinus*, the fifth radial is somewhat rudimentarily represented by a small trigonal piece occupying the right upper corner; that this genus, as yet, had no anal plate, the left corner of the azygous piece being still intact; that in *Hybocrinus* the left side of the plate was taken up by a small anal, and the azygous piece proportionally diminished in size; that in the succeeding stages, which are typified by *Iocrinus*, *Dendrocrinus*, *Homocrinus*, the size of the anal plate gradually increased as the azygous piece diminished; and that at last in *Cyathocrinus* the latter plate was entirely removed, and the anal plate took the position of that in the larva of *Antedon*. These modifications were introduced, as a general rule, in geological succession, but not always uniformly, for in some groups the development went on more rapidly than in others. Such a rapid development took place in *Cyathocrinus*, which existed already in the Silurian, although attaining its maximum representation in the Carboniferous; while in most of the Poteriocrinidæ, which eminently belong to the Carboniferous, the very opposite is observed. The most remarkable deviation in this respect is shown by the symmetrical Silurian genus *Codiacrinus*, which apparently has neither azygous nor anal plate.

The final resorption of both plates is best shown in the Poteriocrinidæ. In *Poteriocrinus*, *Eupachycrinus* and *Zeacrinus*, the azygous plate is comparatively well developed, but completely pushed out of the radial position which it had previously occupied. In these genera the anal plate is small, and the first

plate of the tube forms a part of the calyx. The allied *Graphiocrinus*, however, has no azygous plate, and the posterior basal, which is somewhat elongate, supports upon its truncate upper end only an anal plate. In *Ceriocrinus*, which is in a similar condition, the anal plate is partly lifted out from between the radials, and extends half way beyond the articular faces of these plates. In *Erisocrinus*, the anal plate is not only smaller, but rests wholly upon the radials, beyond the limits of the dorsal cup. Finally in *Encrinus*, this plate seems to have been entirely removed in the adult. We have a specimen of *Encrinus liliiformis* only an inch in length, including the arms, which contains between the arms a row of four conspicuous, slightly convex plates, the upper one triangular, which we regard as plates of an anal tube. This discovery is of some importance, as it tends to prove that *Encrinus* is not a Neocrinoid, but a highly-developed Poteriocrinoid.

In the Silurian *Triacrinus* and *Pisocrinus*, which we arrange under the Symbathocrinidæ, we find dorsally no anal plate, but simply an azygous piece. This supports both posterior radials, which are less than half as large as the two antero-lateral ones, and join laterally. In the Carboniferous genus *Symbathocrinus*, however, the azygous plate is wanting, the radials are almost equally developed, and these support a small anal piece. In the allied *Stortingocrinus* and in *Stylocrinus* (*Symbathocrinus* of Miller and Schultze), although exclusively Devonian genera, we find neither azygous nor anal plate, but *Phimocrinus*, like *Symbathocrinus*, possessed a large anal aperture between the highly extended articular facets of the radials, and may have had an anal plate. Whether the summit plates of the two former genera had reached the advanced state of *Symbathocrinus*, or were yet in the condition of *Haplocrinus*, cannot be ascertained from any of the specimens, but it may well be doubted. In *Haplocrinus* the anal opening is pierced through one of the interradials, and the same may be the case in *Stortingocrinus* and *Pisocrinus*. In *Coccocrinus* and *Culicocrinus*, the anus is located between the first and second radials, piercing the one as much as the other; in *Platycrinus* above the first interradial, being separated from the proximals by a special anal plate.

It has been stated that the Inadunata possess no higher orders of anal pieces, and that the plates succeeding the first, form a

part of the tube. They do not all, however, have the tube well developed, and in some of them it is altogether unrepresented. *Haplocrinus* has a simple anal opening, and herein deviates from most of the other genera of this group. The Hybocrinidæ and *Cyathocrinus alutaceus* have only a short protuberance, composed of small plates.

The simplest tube is found in *Catillocrinus* and *Calceocrinus* (Pl. 5, figs. 15, 16), in which it consists of a single row of very large solid plates, transversely curved like an arm-joint, with a semicircular groove along the ventral side. This groove, which extends from the base of the tube to its distal end, is open in all our specimens. A somewhat similar tube occurs in *Symbathocrinus*, in which the proximal plates at the posterior side are considerably thicker than those upon the other sides.

More important from a morphological standpoint, is the ventral tube of the Heterocrinidæ, Anomalocrinidæ and some Silurian Cyathocrinoid genera in which the anal piece, as in *Catillocrinus*, is succeeded by a row of heavy curved plates, which on the dorsal side pass up to the end of the tube. These plates are bordered laterally by several rows of delicate pieces, pierced by pores or slits along their sides, the whole forming a sac-like appendage. It is very evident that this row of dorsal plates is identical with that of *Catillocrinus* and *Calceocrinus*, and also that the ventral side of the tube in the latter two genera was closed by plates in a similar way.

A still higher form is represented by the later Cyathocrinidæ, which have no such row of dorsal plates, the entire sac being composed of delicate pieces. Most of these are perforated with pores, with the exception of the proximal rows of plates dorsally, which are solid, and also frequently those crowning the distal end; while those facing the ventral side are more or less perforated. Among the earlier Poteriocrinidæ, the sac is large, either cylindrical, club-shaped, conical or balloon-shaped, and it often extends beyond the tips of the arms. In the later Poteriocrinidæ, however, the sac dwindles down to a short cone, even in the asymmetrical *Eupachycrinus*, and it has apparently no pores, at least not dorsally.

In most of the Camarata the anal plate is placed between the first radials, and occupies the lower portion of the dorsal cup. In the Rhodocrinidæ, in which the first interradials alternate with

the first radials, the posterior interradial takes the functions of the anal plate, and the second order of interradials, which consists of two pieces, generally contains the second anal with additional plates above. The anals, as a general rule, are arranged longitudinally, but the row is often interrupted by intervening interradials. In *Reteocrinus*, in which the interradial series consists of small irregular pieces, the posterior side is divided equally by a vertical row of large convex anals, arranged like the plates which constitute the dorsal side in the tube of *Catillocrinus.* The only essential difference between the two structures is that the plates in the latter form a free appendage, similar to that of *Thaumatocrinus*, while those of *Reteocrinus* and *Xenocrinus* are incorporated into the calyx.

All typical Actinocrinidæ, Glyptasteridæ, Barrandeocrinidæ, Acrocrinidæ and Hexacrinidæ have a special anal plate between their first radials, and in most of them the first posterior interradial is split into two halves to receive the second anal plate. However, in *Actinocrinus* and allied genera which we separated under Actinocrinites, the second anal is pushed up to the line of the secondary interradials, although the first interradial, as in the other groups, is divided. The splitting of the first interradial for the reception of an anal piece, to which we have alluded, is of the utmost importance for the study of the summit plates, as we find the same thing there repeated among the proximals.

In the Melocrinidæ the first interradials are undivided, and in most of them the lower anal plate is inserted between the two secondary interradials; in others, however, which have no anals within the dorsal cup, the anals commence at the equatorial zone. In the Platycrinidæ the first interradial of the posterior side is considerably larger, and evidently consolidated with the first anal plate. In the Calyptocrinidæ, finally, the whole calyx, dorsally and ventrally, is strictly symmetrical, the anus central, and the only asymmetry in their structure is found among basals and proximals.

The anal opening in all Camarata is located at the distal end of the tube, whether this terminates within the calyx or is extended into a proboscis, and its position is more or less lateral, except in the Calyptocrinidæ in which it penetrates the central piece. The plates composing the tube of the Camarata are abactinal, and form a part of the posterior interradial series; they

are strong, rigid, without pores, are suturally connected, and their arrangement is irregular. This tube differs essentially from the ventral sac, which forms a part of the disk, and is composed of anambulacral plates, into which the plates of the abactinal tube are incorporated, in a similar manner as the higher radials and proximal pinnules are into the disk of the Neocrinoidea. Moreover, the ventral sac does not contain the anal aperture, which is generally located within the disk. For further consideration of this organ we refer to our chapter on the perisomic plates.

Among the Articulata, the Crotalocrinidæ and Cleiocrinidæ have an anal plate in lateral contact with the radials. The same is the case in the Ichthyocrinidæ, with the exception of *Ichthyocrinus*, which has dorsally no anal plate and generally no interradials. *Pycnosaccus*, *Calpiocrinus*, *Homalocrinus*, *Lecanocrinus*, *Gnorimocrinus* and *Mespilocrinus* have even an azygous piece, which is absent in *Anisocrinus*, *Taxocrinus*, *Onychocrinus*, *Forbesiocrinus* and *Lithocrinus*. An anal appendage has been observed only in *Crotalocrinus* and *Enallocrinus*, located ventrally, close to the periphery. In the former it consists of a tube composed of eight vertical rows of heavy quadrangular pieces, connected by suture. In *Enallocrinus* its form is unknown.

In Part I we described *Taxocrinus*, *Onychocrinus* and *Gnorimocrinus* as having a small lateral tube resting upon the first anal plate. To this Dr. P. H. Carpenter objected in his paper on *Thaumatocrinus* (Philos. Trans. Royal Soc., 1884, pt. iii, p. 928). He admitted "that the arm-like series supported the lower portion of the anal interradius," but doubted "that the plates had been hollowed out on their inner side for the reception of the hind-gut," which "undoubtedly opened to the exterior at a higher level through a regular anal tube, just as in other Crinoids." These objections are well founded, and we are now fully convinced that those plates were bordered laterally by interradial pieces as in *Reteocrinus*.

THE PLATES OF THE ACTINAL SYSTEM.

A. *The Summit Plates.*

The *summit plates* consist of the actinal plates, overlying and immediately surrounding the peristome. For these plates we have heretofore proposed the name "apical dome plates," but

finding its application somewhat cumbersome, as the word "apical" is used in a different sense, we have abandoned it. The summit plates are represented in the Palæocrinoidea by the *central piece*, the six or more so-called *proximals*, and the *radial dome plates;* in the Neocrinoidea, by the *oral* plates alone.

The orals constitute important elements in the ontogeny of recent Crinoids. They appear at first in the form of a closed pyramid, composed of five triangular plates.

According to Dr. P. H. Carpenter (Chall. Rep., p. 71), "their rudiments appear in the free-swimming larva simultaneously with those of the basals, which are developed spirally round the right peritoneal tube; while the orals appear in a similar spiral around the left one. The skeleton is at first limited entirely to these two rings of plates, the edges of which meet around the equator of the growing cup, though they ultimately become separated by the appearance of the radials between them. At the base of the closed pyramid formed by the oral plates is the upper portion of the larval body, in the centre of which the opening of the mouth is formed. . . . At a certain period of development, the five valves of this oral pyramid gradually separate so as to open the mouth to the exterior, and allow the protrusion of the tentacles, while the floor of the original tentacular vestibule, with the mouth in its centre, becomes the peristome of the growing Crinoid." Afterwards the orals become "completely separated from the basals and radials by the equatorial perisome and are relatively carried inwards, while the second radials project somewhat outwards. . . . The orals are thus left as a circlet of five separate plates protecting the peristome in the centre of the upper surface of the disk." In all Pentacrinidæ and also in the Comatulæ, with the single exception of *Thaumatocrinus*, the orals eventually undergo a process of resorption, while in *Rhizocrinus*, *Hyocrinus*, *Holopus* and *Thaumatocrinus*, they persist through life.

Nothing is known of the orals in Mesozoic Crinoids.

That the orals, which assume such an early prominence in the ontogeny of the later Crinoids, should be unrepresented in palæozoic ones, seems scarcely possible. This has been conceded by various writers, but there is, as yet, much difference of opinion as to the plates which represent them.

The first writer who referred to oral plates in palæozoic

Crinoids was Prof. Allman. He suggested an analogy between the transition stage of *Antedon* and the permanent condition of *Haplocrinus*, *Coccocrinus*, *Stephanocrinus* and *Lageniocrinus*. In these genera he took the plates covering the ventral surface to be the orals. We have already shown that the ventral pyramid in *Haplocrinus* and *Coccocrinus* is composed of interradials and not of orals, and the same may be said of *Stephanocrinus;* while the so-called orals in *Lageniocrinus* are radial in position, and evidently arm pieces.

The next writer on this subject was Prof. Zittel, who thought these plates were present in *Haplocrinus*, *Coccocrinus*, *Symbathocrinus*, in the Cyathocrinidæ, Hybocrinidæ and Crotalocrinidæ. That the so-called orals in the Cyathocrinidæ and Hybocrinidæ are interradials can no longer be doubted; while the orals of Zittel in *Symbathocrinus* prove to be merely articular extensions of the radials, which, in their form, somewhat resemble the orals of recent Crinoids. The so-called orals in the Crotalocrinidæ are identical with the proximals (nobis), and will be discussed in connection with them.

De Loriol substantially accepts Zittel's classification, and also his interpretation of the plates.

Dr. P. H. Carpenter, in the Challenger Report, no longer regards the large interradial plates in the Cyathocrinidæ and Blastoidea as orals, but, as before, he applies the term to the interradials of *Allagecrinus* and *Haplocrinus*, and to the inner ring of interradials in *Coccocrinus*. He also designates as orals the *six* proximals surrounding the central piece, and calls the latter the "orocentral." He further states that orals were "represented in the vault of all Palæocrinoidæ, whether simple or complex, although they are sometimes very greatly reduced." Carpenter's views agree essentially with those of Zittel, only that he extends the term to the proximals in all cases, while Zittel applies it exclusively to those of the Crotalocrinidæ. According to his description, the vault in the Platycrinidæ is paved with well-developed "Centralplatten," and in his general remarks on the Actinocrinidæ he speaks of "seven Scheitelplatten," surrounded by a greater or smaller number of radial and interradial plates.

As for ourselves, we have described orals in *Haplocrinus*, *Coccocrinus*, and in the Cyathocrinidæ; but, as already stated,

later investigations have convinced us that the so-called orals in all three groups are calyx interradials. At no time, however, have we held these plates to be structurally identical with the proximals.

Before attempting to determine the identity and relationship of the oral plates in the older Crinoids, it will be necessary to give a full description of the different plates which constitute their summit.

The central piece, as a rule, is the largest plate of the ventral side. It is not only the centre of figure, but also the centre of radiation, and as such occupies the same position ventrally as the basals occupy on the dorsal side. It is frequently nodose, even spiniferous, but always more or less convex, and has a concavity upon its inner floor, toward which all organs from the arms concentrate. The central piece is surrounded variously by from seven to twelve other plates; four of these are larger than the others, interradial in position, and each one rests upon, and connects with, one of the four regular interradial series. Toward the posterior side there are three smaller plates (Pl. 7, figs. 2, 5, and Pl. 8, figs. 7, 8), rarely two (Pl. 7, figs. 6, 7, 8), which similarly connect with the azygous interradius. The three smaller pieces are frequently separated from the larger ones at each side by a good-sized plate, radial in position (*Xr* in Pl. 7, figs. 3–10, and Pl. 8, figs. 1, 3); sometimes, however, they unite laterally with the larger ones. This is the case in the simpler forms, such as *Symbathocrinus* (Pl. 5, fig. 12), and in *Cyathocrinus alutaceus*. In very complex genera, and especially among the huge forms of the Actinocrinidæ, the four larger plates are also separated by radial structures, generally by three plates longitudinally arranged (Pl. 8, figs. 1, 3, and Pl. 4, fig. 4), of which the inner ones abut against the central piece, the outer ones against the second radial and against the sloping sides of the four large proximals. In species in which the latter are laterally connected, which is much more frequently the case, there is but one radial plate, and this takes the position and functions of the third one. In species with a single radial, this rests at the three anterior rays within the angles formed by the four large proximals; while the plates of the two posterior rays are often laterally inserted between the larger and smaller proximals, abutting against the central piece. These two posterior radials were thought by us, and, we suspect,

also by P. H. Carpenter, to represent a bisected proximal, and the two or three plates which they enclose were supposed to be anals or plates of the anal tube—a mistake easily explained by the fact that the plates stand in line with, and join the four large proximals, and have very near their size. We discovered our mistake when we found that in all internal casts the radiation follows the median line of the plates, and not the suture, as in the case of the proximals. The disturbance in the arrangement of the two posterior radials is evidently due to the anal structures, which pushed these plates out of their regular position. In species with a large subcentral anal tube, the position of these radials is so completely altered that they are sometimes actually placed within the semicircle of the four large proximals. Such is the case in the specimen of *Teleiocrinus* (Pl. 4, fig. 4), in which the anal appendage is almost central. In this specimen, all three anterior rays have three primary radials, while the two posterior ones have four. The inner plates serve as a kind of axillary for the ambulacra of the postero- and antero-lateral rays, which are undivided for some distance, giving off underneath a branch to the outer radials. The presence of a fourth radial is rather an exception, and, indeed, three radials are found, as far as we know, only in the larger species of the Actinocrinidæ. In species in which the covering plates pass out to the surface of the vault, the radial dome plates are frequently either wanting in the three anterior rays, or they are exceedingly rudimentary and very irregular in form, while those of the posterior rays are generally intact (Pl. 7, figs. 3, 9, 10). But in some species the posterior radials are partially or totally resorbed (Pl. 7, fig. 8), and the covering plates pass out directly from beneath the central piece. In *Melocrinus* and *Cyathocrinus alutaceus*, in which the anal structures are comparatively narrow, the central piece being generally surrounded by only six plates, of which two face the posterior side—all five radials are placed outside the ring of proximals; but we have a specimen of *Melocrinus Konincki* in which, exceptionally, the plate of the right postero-lateral ray is placed in line with the proximals. Another interesting departure from the general rule is found among the larger species of *Dorycrinus*, *Megistocrinus* and *Agaricocrinus*, in which the central plate is isolated from the proximals by a belt of small pieces. Not even the proximals are connected with the radial dome

plates, nor with one another, and each summit plate has a totally isolated position. In the smaller species and younger specimens, however, all summit plates are connected, showing that those small inserted plates result from excessive growth, and are introduced to increase the capacity of the visceral cavity.

Higher orders of summit radials exist in comparatively few genera. We must admit that the descriptions which we gave of these plates, although correct as to certain species, cannot be applied to the Palæocrinoidea generally, nor even to all Actinocrinidæ. Many of them have but a single radial, and the plates which we took to be radials in most of them, prove to be interaxillaries and interbrachials, which often attain a larger size than the surrounding plates. A very conspicuous case of this kind is *Dorycrinus*, in which the large spiniferous plate above each ray is not a primary radial as we had supposed, but an interaxillary, for the bifurcation of the ambulacral tube takes place beneath the preceding plate. The misconception of these plates in this and other genera led us to suppose that the arrangement of some of the summit plates was more or less disturbed in all species with a large number of arms, while in fact we had searched for plates which are unrepresented. The arrangement of the summit plates, as a rule, is very regular, and only disturbed by the anal tube. They are readily recognized even in *Megistocrinus*, *Strotocrinus* and *Teleiocrinus* as seen by our diagrams (Pl. 8, figs. 1, 3, 5, and Pl. 4, fig. 4).

It has been stated that the proximals, in all cases in which they have been recognized by us, consist of more than five plates, generally of seven, and we have asserted, which has been accepted by Carpenter (Chall. Rep., p. 167), that the two outer plates at the azygous side are equivalent to, and take the place of a fifth large one, being separated from each other by anal plates or the proboscis. The structure is well shown by our diagrams, but in examining them it must be borne in mind that the plates marked *Xr* are radials, and not interradials as heretofore supposed. The more central the position of the anal aperture, and the larger the size of the tube, the greater is the disturbance in the general arrangement of the summit plates. This might be expected, but it is certainly very remarkable that the azygous proximal is divided also in species in which the position of the anal opening is lateral or dorsal, and totally

outside the ring of proximals. Yet such is the case in *Megistocrinus Evansii* and in *Megistocrinus brevicornis*, in which the anal tube is extremely small, located beneath the arm regions, and separated from the proximals by from ten to twenty rings of plates. At the azygous side they have two well-defined proximals, separated by irregular small plates, in a similar manner as in other groups. If these pieces were orals, as asserted by Carpenter, it is difficult to understand why they should be divided in these species, especially if we take into consideration that the orals in all recent Crinoids, even in the asymmetrical *Thaumatocrinus*, consist of five undivided plates.

There is not a single instance known among recent Crinoids in which the anal opening penetrates the orals, not even in the early larva, in which the oral pyramid occupies the whole ventral surface. In the larva the opening is placed within the equatorial zone, beneath the orals, and the same is probably the case in *Holopus*, in which the orals retain permanently the condition of the larva. In the more advanced stages, the anal opening is carried inward by the gradually increasing perisome, but it remains outside the oral ring in all cases, whether the orals become absorbed as in *Pentacrinus*, *Bathycrinus* and *Antedon*, or are retained permanently as in *Rhizocrinus*, *Thaumatocrinus* and *Hyocrinus*.

In the face of such evidence it seems to us extremely hazardous to assert that in Palæozoic Crinoids the anus penetrated the orals, or was closely connected with them. But we must make this assertion if we are to accept the interradials in *Haplocrinus*, and the so-called proximals in other genera, as the representatives of the orals. We might account for a slight disturbance in the form of the plates in genera in which the anus, or its component parts, come in direct contact with the plates,[1] but in our opinion no explanation whatever can be given why in such forms as *Megistocrinus*, *Crotalocrinus*, etc., the posterior oral plate should be divided. For the same reason we cannot accept the five interradial plates in *Haplocrinus* to be orals. If *Haplocrinus* was in

[1] There is a case in which the anus penetrates the central piece. In the Calyptocrinidæ in which the whole calyx—with the exception of the basals—is symmetrical, the anus is strictly central, and the proximals completely pushed out of position, the central piece is bisected, and the two halves, jointly with the proximals, form the sides of the anal tube.

the condition of the Pentacrinoid larva, as suggested by Carpenter, it should have its anal opening beneath the orals, and not pierced through the upper portion of one of them. The very fact that the anal structures are invariably connected with the proximals, proves to us that the latter are interradials, developed around the left peritoneal tube, in a similar manner as the calyx interradials around the right, and that, as such, they are homologous with the first interradial plate in the calyx, and not with the basals, as suggested by Carpenter. The interradials, and not the basals, enclose the anal plates; there is not a single instance known to us in which an anal plate enters the basal ring. The azygous side of the proximals is generally composed of three adjacent pieces transversely arranged, and a divided interradial, which encloses an anal plate, as in the case of the primary calyx interradials. Sometimes, however, the anal plate is lifted out, and the first row is occupied exclusively by a bisected proximal (Pl. 7, figs. 8–10), as in the apical system of *Actinocrinus*.

It has been observed by Goette (Vergleichende Entwickelungsgeschichte d. *Comatula mediterranea*, Arch. f. Microsk. Anat., 1876, Bd. xii, pp. 621–624), that there exists a complete homology between basals and orals, and that both were developed spirally, the former round the right, the other round the left peritoneal tube. Upon these important observations, with which we fully agree, Carpenter undertakes to build up his proof that the proximals are the orals of the Palæocrinoidea. He reasons as follows (Chall. Rep., pp. 169, 170): "The basals are primitively next to the abactinal centre in Urchins and Stellerids, and are only removed from it in the Crinoid by the growing stem; while the orals are next the actinal centre, no plate being developed there, however, in the recent Crinoid. Did it appear, it would only be in the way, and have to undergo resorption to a greater or less extent, just as the dorsocentral of many Urchins is more or less completely resorbed after the appearance of the anus."

The discovery of a dorsocentral plate in the larva of the Urchins, Starfishes and Ophiurids by Carpenter, Sladen and Lütken, which Carpenter thinks is represented by the terminal plate at the base of the larval stem in Comatula, is to our minds no proof, in the total absence of embryological evidence, that there was a similar plate at the oral side. The so-called "orocentral" is said to be present exclusively in Palæocrinoids, but there it is found in all

of them. It is difficult to believe that a plate so prominent, and so universally represented among the older forms, should be unrepresented in the larva of recent Crinoids before the opening of the oral pyramid. Carpenter's argument, that if the plate was present in the larva it would be in the way, and have to undergo resorption, is certainly not a strong one, for he admits in the Urchins a partial resorption of the dorsocentral after the appearance of the anus, and similar resorptions are going on constantly in the growing Crinoid.

Carpenter's arguments respecting the orals are based essentially upon the existence of an orocentral plate, and if this cannot be proved, his whole oral theory must fall to the ground. In the recent Crinoids, he states : "The embryological evidence clearly indicates that the basals of the abactinal system are represented in the actinal system by the orals. The former are within the ring of radials and next to the dorsocentral ; and it seems, therefore, only natural to regard the six proximal interradial plates, surrounding the central piece (orocentral) in the vault of a Palæocrinoid, as representing oral plates."

Admitting that the terminal plate at the base of the larval stem in the Comatulæ represents the dorsocentral of Stellerids and Urchins, a question which we will not discuss, and admitting further, that a similar plate existed dorsally in the young Palæocrinoid, which we have good reason to doubt,[1] we cannot make out the affinities that are said to exist between this plate and the central piece, the so-called "orocentral." The former is the outer end of a mere transitory appendage, which in the growing animal soon withers off, and which is attached to the outer face of the skeleton, forming no part of it. The latter is a permanent plate, which rests within the test and fills a conspicuous place in it. It is the most important plate in the

[1] We have examined a large number of roots, and have in our collection five perfect Crinoids from the tips of the arms to the ends of the rootlets. In all of them the column runs out into numerous branches, which all come to a point, having no special terminal plate. It is evident that the majority of the older Crinoids, either must have lived in a kind of oozy ground, or they led a half-free life in the adult, using the root as an anchor. In the Lower Silurian only we find attached to corals or shells isolated disks, with a pit at the centre, which may represent the terminal plates of *Glyptocrinus*, but nothing like this has ever been found elsewhere.

summit, as it covers the mouth, and lodges underneath the annular vessel, which is the origin and centre of the whole ambulacral system. As such it has not only the position but performs the functions of the closed oral pyramid in the Pentacrinoid larva. Why, therefore, should the proximals be the orals, and the central piece represent something else that is totally unknown in Crinoid ontogeny, and among Echinoderms generally? The proximals, as a rule, surround the peristome, but do not cover it. The tentacular vestibule is closed by the central piece. This is well shown in our specimen of *Batocrinus Christyi* (Pl. 5, fig. 6), in which the perisomic plates extend up to the central piece. Other specimens (Pl. 4, fig. 4, and Pl. 8, figs. 1, 2, 5) show that the radiations pass out from beneath the central piece, and not from beneath the proximals. If there had been such a thing as an "orocentral," it is difficult to understand how this plate could have entered the "oral ring," unless it was developed in the early larva, as the proximals remain permanently closed. The Palæocrinoids, as a rule, have a central piece, but they do not all have proximals, and it is very significant that the proximals are absent in the earliest Silurian genera, and are most conspicuous in the later and higher types. *Heterocrinus juvenis* is evidently in the same morphological condition as *Haplocrinus*. The ring of plates, which Carpenter no longer considers orals in *Cyathocrinus*, encloses a central piece without proximals, and in all probability the same is the case in *Hybocystites* and the Hybocrinidæ generally. The Reteocrinidæ possess only a small central piece, but have no proximals. Are the orals here resorbed, and also the interradials? That would, indeed, suggest a very peculiar condition for a Lower Silurian genus.

The basals, as pointed out by Carpenter, are the most important plates in the calyx. They lodge within their cavity, bounded by the radials, the chambered organ, which is the centre of the nervous and vascular system, and from the basals the axial canals pass out to the radials and arms. In the summit, the central plate occupies, in relation to the radials, the same position as the basals. It is the only summit plate that is represented in every Palæocrinoid, and it lodges underneath the most important organs of the oral system. In view of these facts, and admitting that the orals are the homologues of the basals, there can scarcely

be a doubt that the central piece, undivided as it is, is the true homologue of the oral pyramid as represented in the Pentacrinoid larva.

It is true that the pentamerous nature of the orals is an objection to this interpretation, but we do not believe it a serious one, certainly not so great as is found in attempting to homologize six proximals with five orals.

Of the embryology of the Palæocrinoidea little or nothing is known except from phylogenetic evidence, and even this is limited, and gives information only as to the later stages in the almost fully developed Crinoid. In recent Crinoids, from their earliest stages, the orals are composed of five distinct plates, and it is very possible that the central piece, if representing the orals of the Palæocrinoidea, primitively consisted also of five pieces, which were fused together, and that the suture lines gradually were obliterated by deposition of new material at the outer surface, as in the case of the underbasals in *Agassizocrinus*. Who would have thought that in this genus the thick plate at the dorsal end represented five anchylosed plates, if the sutures had not been fortunately observed in some of the younger specimens? That a similar process probably took place at the outer face of the central piece, is somewhat indicated by the condition of the plate, which is always more or less conical or spiniferous, and wherever the point of the plate has been broken, the missing part is replaced by secretion of new deposit. It seems to us that in a group like the Palæocrinoidea, in which the tentacular vestibule was permanently closed, a gradual anchylosis of the five primary plates is deducible from analogy, and would be in entire accordance with prevailing rules in nature.

Such an anchylosis occurred in palæozoic times among the basals, and this is of considerable importance, as the basals are admitted by Carpenter to represent the orals. In the larva of *Antedon*, the basal ring is formed of five distinct plates, and the same number prevails in the adult throughout the recent Crinoids, if not throughout the Neocrinoidea generally. Among monocyclic Palæocrinoids, however, this number forms the exception, and occurs only in a few Silurian genera. Five are soon succeeded by four, three and two plates. Carpenter finds no objection to call all those plates basals, and to regard them, whether composed of two, three or five plates, as the representatives and homologues

of the orals. Similar modifications occur in the number of underbasals, and among them Carpenter admits three and four plates; but when we find the underbasals in *Stemmatocrinus* evidently fused together to a single piece, he regards this as a stem joint.

Even the joints of the column are sometimes tri- or quinquepartite, from the top of the column to the end of the rootlets, and principally in Lower Silurian genera; nevertheless the stem joints of the Pentacrinoid larva, and those of the Neocrinoidea generally, are undivided throughout. Are we to consider the former as different elements from the latter because they are composed of three or five pieces? Or are we to regard the five plates collectively as the homologues of the undivided joints of recent and other Crinoids? In the latter case, why should not the dorsocentral, *i. e.*, the terminal plate of the column, be divided in one or the other species? That the plate is undivided in the Pentacrinoid larva, and in the few species of *Pentacrinus* in which it has been observed, is by no means a proof that it is so in all Crinoids.

It has been stated by Carpenter that "the basals are within the ring of radials, and next to the dorsocentral." This is no doubt frequently the case, but is not the universal rule. In the Rhodocrinidæ and Reteocrinidæ the interradials are placed between the radials, forming with them a ring of ten plates around the basals, while in the Acrocrinidæ the radials are totally isolated from the basals by a wide belt of plates, which, although not true interradials, may be fairly compared with them (Pl. 8, fig. 1).

At the oral side, the arrangement is fundamentally the same as in the calyx, as can be observed in species in which all summit plates are fully developed. Frequently, however, the first and second radials are orally unrepresented, when the third radials occupy the same position as their representatives in the calyx, which is the same as that occupied by the third summit radials of *Strotocrinus*, etc.

If the orals were represented by the proximals, the latter should be succeeded in all cases by the radials, and not be included in the same ring. There is not a single instance of Crinoids known to us where either a radial or an anal plate entered the basal ring, or where an anal plate entered the

ring of orals, yet all of this must be encountered if we consider the proximals to be the orals. Moreover, in *Strotocrinus* and *Teleiocrinus* the two posterior radials would be placed inside the oral ring, the orals of *Megistocrinus* would enclose a large circlet of interradial pieces; while in *Reteocrinus*, *Glyptocrinus* and other Silurian genera, the orals would be altogether unrepresented. All these difficulties are removed if we regard the central piece as the representative of the oral pyramid, and the proximals as summit interradials. Basals and radials, interradials and anal plates are then found to occupy the same position orally as aborally, and even the small intercalated pieces in the dome of *Megistocrinus* are explained by analogous plates in the calyx of *Acrocrinus*. But on the contrary, if the proximals were the orals, it would follow that the orals were represented in the calyx by the proximal interradials, and not by the basals.

That the proximals, which are such prominent plates in the Palæocrinoidea, are unrepresented in the Neocrinoids, is fully explained by the fact that in the latter the interradials generally were imperfectly developed in the calyx, and hence their absence in that group cannot be considered a serious objection to our views.

We are convinced that neither the underbasals nor the dorsocentral are represented at the summit, especially not the latter. We cannot imagine what office such a plate could possibly have had at the oral side, considering that it constitutes a part of the column, and the Echinoderms at no time, or in any group, were attached at their oral side. That it is represented dorsally in the Stellerids and Urchins is natural, as it represents there in a wider sense the entire column of the Crinoid, but its presence at the oral side would be an anomaly.

It seems to us that a far less object onable explanation of the central plate than that given by Carpenter, would be to regard it as a posterior oral. In this case the orals would be represented by five plates and not by six; the anus would be placed outside the oral ring, and the radial dome plates would occupy the same position towards the orals as the calyx radials toward the basals. But it would place the mouth underneath the posterior oral, and it offers no explanation of the central piece in *Haplocrinus*.

This view was, perhaps, taken by Zittel in the case of the summit plates of *Crotalocrinus* and *Enallocrinus*, in which the

central plate has a somewhat elongate form, and which he described as having five orals. The summit plates in both genera are subtegminal, being covered completely by interradials, and the same was probably the case in the allied Ichthyocrinidæ, at least in their earlier forms. *Reteocrinus* and *Xenocrinus* were evidently in a similar condition, but it is not known whether they had summit plates beneath the interradials or not. *Glyptocrinus* and most of the Silurian genera of the Camarata had a central piece, but no proximals. In all Devonian Crinoids both plates are generally represented, but they do not attain their full development until the Carboniferous.

It has been asserted by us that the ventral plates in *Allagecrinus*, *Haplocrinus*, *Culicocrinus* and *Coccocrinus*, are calyx interradials and not proximals. In *Allagecrinus* and *Haplocrinus* there are five single plates occupying the same space as the whole series of interradials in other genera. In their simplicity, and in resting upon the radials and closing the peristome, these plates, no doubt, closely resemble the orals in the Pentacrinoid larva, but as calyx interradials they would occupy exactly the same position. There is, however, a very important difference in the structure of the two forms to which no attention has been paid. The orals of the larva and those of *Holopus* rest loosely upon the calyx; while the interradials of *Haplocrinus*, like all other interradials, are united with the radials by a close suture.

It has been proved from palæontological evidence, that in the earlier genera the interradials are more extravagantly developed than in later ones. In *Crotalocrinus* and *Reteocrinus*, the interradials cover the entire ventral surface; in *Glyptocrinus* and *Glyptaster* they extend to the central plate; while in the Carboniferous genera they recede gradually toward the periphery, and the central space is filled by large proximals, and often by radial dome plates. Considering these facts, is it safe to assert that in *Allagecrinus* and *Haplocrinus*, which are regarded as larval forms, interradials are entirely absent, and that all ventral plates are actinal? Is it not more reasonable to imagine that in these low forms the ventral side was covered by the one plate, in a similar manner as in *Crotalocrinus*, *Reteocrinus and Glyptocrinus* by the whole collection of plates? In the Neocrinoidea, from the larva to the adult, all ventral plates are actinal, but in all Palæozoic Crinoids, and we may say in all Palæozoic Pelmatozoa,

the whole, or at least the greater part of the ventral side, is abactinal, and this we consider one of the best distinctions between the two groups. We do not understand how Carpenter can maintain that those plates are orals, and at the same time can retain *Allagecrinus* and *Haplocrinus* under the Palæocrinoidea. He must either refer them to the Neocrinoidea, or accept the so-called "Scheitelplatten" as interradials in their simplest form.

It seems to us that in *Allagecrinus* the interradials cover not only the disk but also the summit plates. *Culicocrinus* is in a similar condition, but has additional interradial plates. In the somewhat higher developed *Coccocrinus*, the interradials are separated from one another, forming lateral clefts and a central gap, evidently to receive the oral plate and the ambulacra, which, however, retain permanently the position which they occupied before the valves separated, and rest in the bottom part of the clefts. In *Haplocrinus* the interradials evidently separated in the growing animal, and the oral plate moved outward, but not sufficiently to bring it to a level with surrounding plates; while the ambulacra remained subtegminal. The interradials, instead of being formed into lateral clefts as in *Coccocrinus*, remained permanently closed by means of lateral growth, as shown by their beveled edges, which are formed into grooves.

From *Haplocrinus* to *Cyathocrinus alutaceus* and *Symbathocrinus* there is but one step. The latter two have proximals, the former not. The proximals, we think, were introduced in the Palæocrinoidea in a similar manner as the perisomic plates in the Neocrinoidea. The interradials by the increasing width of the calyx retreated in the growing Crinoid toward the periphery, thereby forming an open space around the oral plate which was gradually filled by the proximals and other dome plates. *Symbathocrinus* is a much higher form than *Haplocrinus*, as shown by the presence of proximals, by the ventral tube, and by the highly differentiated mode of articulation.

If it were true that the five interradials of *Haplocrinus* and *Allagecrinus* are homologous with the six proximals of *Symbathocrinus*, *Platycrinus* and *Actinocrinus*, and that these plates are orals, it would follow, inasmuch as all later and complex Palæocrinoidea have six plates, that the larger number represented the higher form. And further, that *Haplocrinus* and *Allagecrinus* had reached a degree of development such as attained only by

Neocrinoidea, but existing among them as a constant character through all stages of growth. In the Neocrinoid larva the orals are large, occupying the entire ventral side, or one-half of the entire test, and the conditions are not changed by the introduction of perisome in the adult. In the adult Palæocrinoid the actinal system of plates is restricted to a small space, and it is very improbable that the orals extended out to the radials in the earlier stages, or in such forms as *Haplocrinus* and *Allagecrinus*, which, as admitted by Carpenter, are in the condition of the Palæocrinoid larva.

All this tends to prove that the resemblance between the proximals and the orals in the adult Rhizocrinite or Thaumatocrinite, and the "Scheitelplatten" in *Allagecrinus* and *Haplocrinus* with the Pentacrinoid larva, is altogether superficial, and that the orals, if these are developed in Palæocrinoidea, which we think they are, can only be represented by the central plate.

A resorption of the summit plates may have taken place in the later Inadunata; throughout the Camarata they persisted through life.

B. *The Ventral Perisome.*

The ventral perisome covers the visceral mass or body, and together with the oral plates, forms the surface of the disk. It is composed of the "ambulacral" and "anambulacral" plates. The anambulacral plates are irregular pieces or limestone particles along the interpalmar areas, which consist of the anambulacral plates proper, and the so-called interradial plates of the disk. The former are pierced by numerous water pores, and occupy the spaces between the ambulacra; the latter are not perforated, and occur in the substance of the perisome, uniting the rays and their subdivisions. These interradials must not be confounded with the calyx interradials, which cover those of the disk. The ambulacral plates extend from the peristomial area to the extremities of the arms and pinnules, and consist of the so-called "Saumplättchen" or "covering plates," and the "adambulacral" or "side pieces" which support the former and border the outer margins of the ambulacra.

In the Pentacrinidæ, the perisome is always studded more or less with plates, and these often have a very solid appearance; while in the Comatulæ the entire perisome is sometimes almost, or totally, free from calcareous incrustations.

Among the earlier groups of the Neocrinoidea, the perisome is only known in the Jurassic *Extracrinus* and in *Marsupites*, in both of which it consists of small irregular pieces, forming a rather substantial pavement, which frequently encloses the lower pinnules. Among Palæocrinoidea, a perisome has rarely been observed, but it was preserved among several groups, and we have been led to the conclusion that the perisome was probably subtegminal in the Camarata, the Articulata, and the earlier Inadunata, but external in the later Fistulata, our former *Cyathocrinidæ*, which we make a branch of the Inadunata.

The perisomic skeleton of the Camarata is frequently preserved in *Batocrinus*, *Eretmocrinus*, *Physetocrinus* and *Dorycrinus*, in which it probably attained a more substantial form than in any of the other genera. It is there composed of rather distinct plates, placed parallel to those of the test or *tegmen calicis*, and arranged in a similar manner. Each plate of the outer test has a corresponding plate in the ventral perisome; the plates of the latter, however, are not connected by suture, but disposed loosely, leaving an open space at each angle, which was perhaps filled by membranous substance. In their usual preservation the plates are frequently dense, owing to incrustations of inorganic matter, but in their natural state they consist of a fine network, and resemble similar plates in recent Crinoids. They form a sort of internal lining, which extends from the second primary radials and first interradials, uninterruptedly, to the central piece, or near it, underlying the proximals and entering the anal tube. This structure is well shown in the specimen (Pl. 5, fig. 6), in which the sutures between central plate and proximals are visible. Most of the perisomic plates, along their median portions, are connected with the plates of the test by small pillars or partition walls, leaving between them open chambers, evidently for the free circulation of water. The water probably entered from without by means of the respiratory pores, which we described in Part I, p. 11, and which jointly may have performed the functions of a madreporite. There are, however, no pillars between the plates along the radial regions, which take the shape of closed galleries or corridors, formed by grooves along the inner floor of the test, and closed from below by perisome. These passages diverge toward the arm bases and contain the ambulacral tubes. The perisome of other genera was prob-

ably less substantial, and perhaps in some of them altogether membranous. We never observed anything like plates in the Actinocrinites, except in *Physetocrinus*, in which they are well developed. Of this genus we lately obtained a specimen which proved that the small tubercles along the ventral surface, figured by us in Rev. ii, Pl. 19, fig. 5, are not, as we then supposed, openings through the "vault," but impressions of the open spaces between the anambulacral plates. In *Actinocrinus* and allied genera we occasionally find little pillars or nodes along the inner floor, which sometimes suspend fragmentary plates, or portions of a filmy substance, and evidently are parts of the perisome. We found similar pillars along the floor of *Glyptocrinus ramulosus* (Pl. 9, fig. 2) underneath the interradial areas, but not beneath the plates overlying the ambulacra. The latter plates are folded as in *Physetocrinus*, and formed into natural grooves, which evidently harbored the ambulacral tubes.

The ambulacral tubes of the Actinocrinidæ rest upon the perisome, but rarely enter the plates of the vault, and do not become exposed until they enter the free arms. In the Platycrinidæ the structure is essentially the same, but the covering pieces frequently enter the calyx at—or close to—the proximals, and in this case often take the form of vault plates. In the young Crinoid, according to our interpretation, the ambulacral tubes were attached to, and rested primarily within the grooves of the lower arm joints, from which they were gradually lifted out when these became incorporated with the calyx and transformed into radials. It seems to us that, while this was going on, the radial regions of the vault were raised by the ambulacra, thereby producing elevations or folds along the vault of *Glyptocrinus* and *Physetocrinus;* while in *Platycrinus* the ambulacra in many cases penetrated the test.

The tubes are composed of four rows of plates, alternately arranged, of which two constitute the floor, the two others the upper side. The upper ones are the covering pieces, but we are not certain whether those at the floor are side pieces or form a sort of subambulacral plates. The covering plates where they entered the vault were suturally connected, but on entering the arms became movable. Side pieces have never been observed in the Camarata, but covering plates are found occasionally both in arms and pinnules, and were probably present in all of them.

We have noticed (Rev. ii, p. 31) narrow grooves upon the inner surface of the vault, which meet beneath the median part of the oral plate, and follow the subtegminal galleries which enclose the ambulacral tubes. The condition of these grooves can be studied most profitably from natural casts, in which they appear as string-like elevations along the ventral surface. They have been observed most frequently among the Actinocrinites, where they seem to be universally developed, while no traces of them are to be seen in the twenty or more casts of *Platycrinus* which we examined. That they do not represent the ambulacral tubes, is proved by the fact that these are always located at a distance from the inner floor, as beautifully shown in the casts (Pl. 4, fig. 5, and Pl. 5, fig. 9), and wherever we found the tubes intact, they occupy the same position. That the strings are in no way connected with the tubes, is further shown by the fact that they always meet in the centre, while the tubes form a ring around the centre, as also by the irregularity which they exhibit. It is shown by our figures (Pl. 4, fig. 4, and Pl. 8, figs. 1 and 3), that there are always two of them side by side, which at places connect, and again at others depart from one another, with irregular knots at each bifurcation. This structure could not be explained if the strings represented the inner cavity of the ambulacral tubes, as these are very regularly arranged. That the grooves are placed along the solid walls of the test, has led us to suppose that they were axial canals, and that these Crinoids possessed an orocentral nervous system like all other Echinoderms, but contrary to the Neocrinoidea, in which the nervous system, as now generally admitted, is connected with the chambered organ within the basal cavity. Our interpretation becomes more plausible when we consider that in the Camarata the radials are never pierced by canals, and it would be difficult to understand how these ponderous arms could have moved without axial cords, unless their movements were altogether passive. That the canals have been observed only in certain groups, may be explained by supposing that in many cases they probably rested against the wall, without piercing the floor.

That the perisome, wherever found in place, extends all the way from the top of the first interradials to the central piece, is very interesting, and shows a complete resemblance between the ventral perisome of a recent Crinoid, and the body beneath the

vault of an Actinocrinoid. A total resorption of all interradial plates, dorsally and ventrally, and also of the proximals, would reduce an Actinocrinoid, or Platycrinoid, essentially to the condition of a Neocrinoid that has its lower arm joints connected by perisome. The fact that the perisome is continued underneath the proximals, and extends to the central piece, tends to prove that the latter, and not the proximals, represents the oral pyramid, as these plates *surround* the peristomial area but do not cover it (Pl. 1, fig. 6). It further proves that the interradial plates of *Platycrinus*, *Glyptocrinus* and *Reteocrinus* cannot be partly plates of the calyx and partly perisomic, but must be either the one or the other. If the Reteocrinidæ had lived in Carboniferous times, and the Actinocrinidæ in the Lower Silurian, there might be a possibility that in the former the interradials, dorsally and ventrally, as well as the summit plates, had been resorbed; but as they comprise one of the earliest known groups, this interpretation need not be considered, and we can only regard those plates as ill-defined interradials.

We find it difficult to believe that the so-called "interradials" of *Guettardicrinus*, and *Apiocrinus roissyanus* and allied species, are homologous with the calyx interradials of an Actinocrinoid; but regard all those pieces as enormously developed perisomic plates. That they are somewhat heavier pieces and more regularly arranged than those plates usually are, is not sufficient to make them calyx plates, as they evidently adapted their conditions to surrounding parts, and are therefore thick plates from necessity, in order to fill the deep edges of adjoining radials. De Loriol, in the Paléont. Franc. on p. 272, describes them in *Apiocrinus roissyanus* as follows: Pièces interradiales nombreuses, très inégales, elles varient dans chaque espace interradial dans le nombre et l'arrangement. Presque toujours la série commence par une pièce unique, hexagone ou heptagone, qui est la plus grande, quelquefois fort grande. . . . Au-dessus il y a deux, trois, et même quatre pièces plus petites, irregulières, polygonales," etc. This description does not apply to calyx interadials, among which the first plate is always very regular, and the first row never consists of two plates, nor the second variously of two, three or four pieces. This irregularity seems to have puzzled Carpenter, for, on p. 183 of the Challenger Report, he suggests that perhaps the "smaller interradials were perisomic plates."

Why not the first plate also? We seriously doubt if those plates enclose the perisome as the interradials in *Actinocrinus*, or were covered by perisome as in *Cyathocrinus*, and hence believe they are not calyx but perisomic plates, which, like the smaller pieces of *Extracrinus*, united the lower arm divisions. We take the same view of the so-called interradials and interaxillaries of *Uintacrinus*, which merely attained the outer form of calyx pieces, but are true disk plates, and on approaching the ventral side passed into anambulacral pieces instead of harboring or supporting a perisome. The case is altogether different in *Thaumatocrinus*, in which the interradials are placed within the ring of first radials, and as such form, like the anal plate, a primitive part of the calyx. The Crotalocrinidæ present a different perisomatic arrangement from the Actinocrinidæ. The interradials frequently commence in the equatorial zone, and extend over the whole ventral surface, even oral plate and proximals being subtegminal. Their perisome, which was figured by Angelin in *Crotalocrinus rugosus* (Icon. Crin. Suec., Pl. xvii, fig. 3 *a*), is composed exclusively of covering plates. The proximals are long and narrow, and abut with their outer edges against the deflected upper ends of two radials, leaving radially five angular spaces, which are occupied by the ambulacra. These ambulacra, of which the covering plates are visible, bifurcate like those of other groups, but their subdivisions, in place of being separated by anambulacral plates, join each other laterally, and, together with the summit plates, fill the entire ventral surface. The total absence of anambulacral pieces in this genus is a most remarkable feature, but may perhaps be explained by the presence of hydrospires. There are, however, no spiracles nor pores through any of the plates, except along the anal tube, which is perforated along its walls.

The vault of the Crotalocrinidæ extends quite a distance into the free rays, as shown by Müller's and Angelin's figures (Icongr., Pl. 6, figs. 6 and 7, also Pl. 25, figs. 15 and 25, and Akademie der Wissenschaften, 1853, Pl. 13, fig. 10). That those plates are not ambulacral pieces is proved by the fact, that they cover the Saumplatten; and have a different style of ornamentation. Those figures further prove, that the ventral covering was pliable, or the arms could not have assumed that horizontal position, and be folded in other specimens. This is of some importance as dem-

onstrating that a pliable vault may enclose another flexible integument and contain the food grooves underneath, which was seriously questioned by Carpenter (Chall. Rep., p. 182). He evidently overlooked *Crotalocrinus*, for we doubt if he could have taken the small covering plates (Icongr., Pl. 17, fig. 3 *a*) for the representatives of the large rigid plates of figs. 6 and 7 on Pl. 6, or the irregular pieces around the oral pole to be summit plates.

Crotalocrinus and *Enallocrinus* have close affinities with the Ichthyocrinidæ, not only in that both have a flexible skeleton, but they frequently possess no interradials dorsally, and they all have the same peculiar arm structure. In speaking of a pliant vault we do not mean a surface "formed of connective tissue with numerous interradial plates imbedded in it," as supposed by Carpenter (Chall. Rep., p. 182), but a continuous integument of plates connected by ligament in place of suture, sometimes with imbricating plates. We postulated the prevalence of this structure in the vault of the Ichthyocrinidæ from the construction of the dorsal plates, which could not be movable unless the ventral side was pliant also. Our views are confirmed by the vault structure of *Crotalocrinus*, and we think the disk ambulacra of *Ichthyocrinus* were arranged in a similar manner, and covered by a similar vault.

A very different perisome is found in the higher types of the Cyathocrinidæ, which is not subtegminal, but exposed upon the surface of the interradial plates. This form is found only in genera in which the ambulacral tubes rest upon the upper edges of the interradials. It is not restricted alone to the later genera, but occurs in several Silurian forms. Angelin has figured such a disk in *Cyathocrinus lævis* (Iconogr., Pl. 26, figs. 2 and 3), and *Gissocrinus punctuosus* (ibid., Pl. 29, fig. 75 *d*), but we think the structure was not correctly understood. In all cases the five interradial plates are completely covered by small perisomic plates, of which those at the four regular sides are not pierced with water pores, while those toward the ventral sac are generally profusely perforated. In some cases we found the summit plates in process of resorption. In *Cyathocrinus iovensis* (Pl. 5, fig. 7), the larger proximals appear in the form of eight irregular pieces, their edges rounded off; while in *Cyathocrinus multibrachiatus* (Pl. 4, fig. 6) only fragments of the plates are scattered over the perisome.

The disk ambulacra were probably differently constructed from those of the arms (Pl. 4, figs. 6 and 7). The specimens indicate that the plates of the former were suturally connected, while those along the arms were movable. All Cyathocrinidæ, so far as observed, have side-pieces which support Saumplättchen; and these rest upon two series of subambulacral (?) plates, which form the floor of a tube as in the Actinocrinidæ.

The "ventral sac" of the Fistulata was always regarded by us as functionally and structurally distinct from the "anal tube" or "proboscis" of the Camarata. We held the former to be an essential part of the body, and perisomic in its origin; the latter as a mere prolongation of the azygous interradius, and constructed of abactinal plates.

To understand the two structures, we must bear in mind that in the growing Actinocrinoid the capacity of the calyx adequately increased with the growth of the body, and hence was at any time capable of holding the visceral mass. In the Fistulata, however, in which all brachials remain permanently free, and the calyx is not enlarged in proportion to the visceral mass, the posterior side of the disk forced its way out through the anal opening, and formed the so-called ventral sac, which has always a narrow neck along the base. According to our interpretation the ventral sac is an enormously developed interpalmar area supported by the anal plate, and as such reminds us of the asymmetrical disk in the recent genus *Actinonometra*, in which the anus is central and the mouth marginal.

In most of the Fistulata, the ventral sac is perforated with round or slit-like openings, transversely arranged, which enter the outer margins of two adjoining pieces, but never penetrate the inner portions of the plates like the water pores of the Neocrinoidea. The openings either extend over the whole surface of the sac; or are arranged in longitudinal rows—porous plates alternating with solid ones;—or the terminal end is composed of large solid pieces, frequently spiniferous; or as in the Carboniferous species of *Cyathocrinus* the entire tube is composed of solid hexagonal plates, and the porous or anambulacral plates are restricted to the small area usually occupied by the smaller proximals. In the Poteriocrinidæ, the anambulacral plates extend over the greater part of the ventral sac, but in the Catillocrinidæ and Calceocrinidæ they are limited to one side of

it. The two latter groups possess a series of large anal plates, arranged horizontally, and these form a proboscis with a furrow at its ventral side. This proboscis was incorporated into the sac in a somewhat similar manner as the lower arm joints and pinnules into the disk of the Neocrinoidea. In this structure the two groups have close analogies with the recent genus *Thaumatocrinus.* In that genus, however, the row of anal plates does not enter the perisome, but forms an independent solid appendage in the shape of a cone, which apparently has no functions, as the anal opening is persomic, and we regard this peculiar appendage as a remarkable instance of atavism.

It is probable that in the latter Poteriocrinidæ and Encrinidæ, the interradials and summit plates became finally resorbed, and the perisome was more or less restricted to the ventral disk, as in these genera the sac dwindled down to a small conical tube, which probably disappeared in *Encrinus* before reaching maturity.

That the openings along the ventral sac are not genital openings, as suggested lately by Trautschold, need not be discussed, as most of the Fistulata have well-developed pinnules, and these are not prehensile organs as supposed by him, but are continuations of the arms which contained the genital glands. Neither is it true that the ventral sac is frequently present or absent in the same species. It existed in every individual, but is rarely preserved in the fossil, and is often obscured by the arms.

Nothing is known from actual observation of the perisome of the Ichthyocrinidæ, and little if anything of the construction of the ventral side in any of their genera. The interradial plates of the dorsal side have been described by us as movable, somewhat irregular in form and arrangement, and upon this, principally, we based our conclusion that the plates of the ventral covering were movable, in some cases perhaps squamous. In *Onychocrinus* only there has been observed by Lyon and us indistinct traces of a ventral covering, but too imperfect to give much information either as to the real nature of the plates, or as to their arrangement. Carpenter regards all interradials of the dorsal side as calyx plates, and all those succeeding them and located ventrally as parts of the disk. We admit that the latter may have a superficial resemblance to the small, irregular and movable perisomic plates of *Extracrinus* and other Neocrinoidea to which he alludes. But we do not understand why a

flexible calyx, with a flexible vault, may not enclose a soft or even a plated disk such as we find in *Crotalocrinus* and *Enallocrinus*. The thinness and irregularity of the plates is no valid argument against it. We find such plates ventrally in *Glyptocrinus* and some species of *Physetocrinus*, and there are plates of the same nature dorsally in the Reteocrinidæ. On the other hand we find massive and more or less regular plates dorsally in *Apiocrinus*, which Carpenter considers to be perisomic. To our minds the case of *Extracrinus* is by no means parallel to that of the Ichthyocrinidæ, as that genus is destitute of calyx interradials. If his argument were correct, then all the plates of the Ichthyocrinidæ and Reteocrinidæ should be considered as perisomic. In that case the perisomic portions of the Crinoid would predominate so enormously that nothing would be left for the abactinal part except the base, and species of *Reteocrinus*, which so good an observer as S. A. Miller considered as congeneric with *Glyptocrinus*, would constitute a distinct order. And we would have the anomaly that the earliest known forms of Crinoids would be in this respect examples of the highest organized types, and most closely allied to the recent Crinoids.

In support of his view, Carpenter has no other proof than this superficial resemblance. There is no evidence of the existence of external food grooves, which must follow if these plates are perisomic. The same reasons that led us to regard the smaller interradials in *Apiocrinus*—massive as they are—as perisomic plates, compel us to consider all plates of the Ichthyocrinidæ, interradial in position, as belonging to the same element, and either all perisomic or all calyx plates.

If the plates in question were perisomic, it would obliterate the last distinguishing feature between Neocrinoids and Palæocrinoids, and we should like to know upon what points Carpenter would separate the Ichthyocrinidæ and Reteocrinidæ from the Neocrinoidæ. We admit that the direct proof of our views as to the ventral structure of the Ichthyocrinidæ is as yet wanting, but in this respect Carpenter is no better off, and it seems to us that the weight of argument from analogy is in our favor.

The Relations of the Palæocrinoidea to the Neocrinoidea.

The name " Palæocrinoidea " was proposed by one of us in 1877 (Amer. Journ. Sci., vol. xiv, p. 190), but not properly defined

until 1879 (Rev. i, p. 30). At that time we also proposed the name " Stomatocrinoidea," and made both groups subdivisions of the "order" Crinoidea, of equal rank with Blastoidea and Cystidea. To the Palæocrinoidea we referred the earlier brachiate Crinoids in which *mouth and food grooves are subtegminal* or hidden from view; to the Stomatocrinidæ the Mesozoic and recent Crinoids in which *mouth and food grooves are exposed upon the disk.* Both groups were admitted by Carpenter and Etheridge, Jr., in 1881, but they changed the name Stomatocrinoidea into " Neocrinoidea" because, as they stated, our name was "long and cumbersome," and they were "by no means sure that some of the Palæocrinoids had not an external anal opening." We might, no doubt, successfully controvert the right of Carpenter and Etheridge to change our name, which had priority, and which was sufficiently defined to be recognized, until they proved satisfactorily that the name-giving characters were inconsistent or incorrect. This view of the case was evidently taken by De Loriol, who in his late work (Paléont. Francaise, tome xi, p. 43) placed both names in equal rank. We hold there is not a single Palæocrinoid known in which either mouth or food grooves are exposed, nor a " Stomatocrinoid " in which they are closed, and this we still regard as one of the best distinctions between the two groups. We, therefore, wish to have it understood that, in accepting Carpenter's name, we do not give up our original position, but yield to the preferable name.

The Crinoidea were subdivided by Joh. Müller into " Crinoidea Articulata " and " Crinoidea Tessellata," the latter including the Inarticulata and Semiarticulata of Miller. Müller's definitions of his groups were extremely vague, but we may conclude from the names and from the genera which he referred to them, that they were based upon a supposed difference in the mode of union of the first radials with the plates which they bear. Among the Tessellata, however, we find *Poteriocrinus* which has highly developed articular facets, not only between radials and brachials, but also at the bifurcations of the arms. Zittel, who adopted Müller's divisions, defined the calyx plates of the Tessellata as " Unbeweglich durch einfache Näthe verbunden ; " those of the Articulata as " durch gelenkartig ausgehöhlte und gewölbte oder ebene Nathflächen verbunden." But nevertheless he refers to the Tessellata the Ichthyocrinidæ, in which the radials are united with one another by ligament and

frequently by muscles also, as seen by the articular faces of *Forbesiocrinus nobilis* (Pl. 5, figs. 3 and 4), and we have seen similar faces in *Ichthyocrinus* and *Taxocrinus.* Among the later Poteriocrinidæ there are also several genera with fossæ along the lateral faces of the radials, which indicate a certain degree of mobility even among the plates of the calyx. On the other hand, the higher radials of the Apiocrinidæ, which Zittel refers to the Articulata, are as solidly united among each other directly, or by means of intercalated plates, as in any so-called "tessellate" Crinoid. All of this tends to prove that a division based upon the mode of union between the plates is totally impracticable, if intended to separate the palæozoic from the later Crinoids, as done by Zittel. We think, however, it affords important data for establishing subdivisions of the Palæocrinoidæ, among which we recognize Articulata and Camarata, the former having their plates connected by articulation, the latter by suture.

The distinctions between the Neocrinoidea and Palæocrinoidea, according to Carpenter (Challenger Report, pp. 149–154), are the following:—

1. In the Neocrinoidea, underbasals are rarely represented; in the Palæocrinoidea, frequently.

2. In the Neocrinoidea "by far the greater number of genera have five equal and similar basals, with five equal and similar radials resting upon them." Exceptions to this rule are found in *Hyocrinus*, which has three basals, and *Holopus* and *Eudesicrinus* in which the radials are not symmetrical; "but this want of symmetry is not due to the intercalation of any anal plate as in nearly all Palæocrinoids."

3. In all Neocrinoidea, with the exception of *Thaumatocrinus*, "the primary radials are in contact with one another by the entire length of their sides; or more rarely, as in *Guettardicrinus*, *Uintacrinus* and *Apiocrinus roissyanus*, their distal angles are cut away so as to receive the lower part of the first interradial. This feature, which is common enough in the Palæocrinoidea, is rare in the Neocrinoidea."

4. Most of the Neocrinoidea have no interradial plates in the calyx, but when present "they are not limited to any special side of the calyx, but are equally distributed all round it, so that there is no distinction of the anal side, *Thaumatocrinus* excepted." In the Palæocrinoidea, however, "the pentamerous symmetry of

the calyx is almost always disturbed by a greater or less modification of the plates on the anal side."

5. In the Neocrinoidea "the basals are pierced by interradial canals or grooves, which lodge the cords proceeding from the angles of the chambered organ," whence they pass into the radials. None of them have permanently imperforate radials as so many Palæocrinoidea, the latter group remaining in an embryonic condition.

6. In the Neocrinoidea, with the exception of *Metacrinus* and *Plicatocrinus*, the axillary is the third of the primary radials; while in the Palæocrinoidea the first radials themselves may be axillary or any other plate beyond the first.

7. The arms of the Neocrinoidea, with the exception of one or two species of *Encrinus*, are uniserial, those of the Palæocrinoidea frequently biserial.

8. The mouth and food grooves of all adult Neocrinoidea are exposed to view; in the Palæocrinoidea, with but few exceptions, closed by plates.

In most of these points we agree with the English scientist, but in some of them we think modifications should be made, and there is one point to which he did not give the importance which we think it deserves.

We agree with Carpenter that underbasals are rarely observed in Neocrinoids, which, as we have stated elsewhere, are built upon the plan of dicyclic Crinoids. The angles of the column are directed interradially, the cirrhi radially; while the opposite is the case in *Actinocrinus*, *Glyptocrinus*, *Belemnocrinus*, *Heterocrinus*, etc., which are known to be monocyclic, and we conclude from this structure that all Neocrinoidea, or at least most of them, in their larval state may have possessed rudimentary underbasals hidden by the column.

Among Neocrinoidea, *Thaumatocrinus* is the only genus in which calyx interradials are evident, and it is very doubtful to us whether even these plates, which rest within the ring of the first radials, really are the homologues of the first interradials of the Actinocrinidæ, Platycrinidæ or Cyathocrinidæ. The interradials of *Thaumatocrinus* were covered in the larva by the oral pyramid; while those of the young Palæocrinoid form the whole of the ventral surface. The so-called "interradials" of *Guettardicrinus*, *Apiocrinus roissyanus*, and *Uintacrinus* we take to be

perisomic plates, and we cannot understand how Carpenter can admit interradials in *Apiocrinus roissyanus*, and not in *Apiocrinus Meriani* (De Loriol, Pal. Franc., tome xi, Pl. 40), *Apiocrinus Rathieri* (Ibid., Pl. 50) and *Apiocrinus murchisonianus* (Ibid., Pl. 53). But it is still more remarkable that in *Apiocrinus roissyanus* Carpenter considers only the first row, and not the succeeding ones also, as calyx plates. The latter are equally solid, suturally connected, and rest like the first plate, between the primary radials.

In our opinion Carpenter lays too much stress upon the asymmetry of the calyx in the Palæocrinoidea, which he attributes to the intercalation of an anal plate. If the asymmetry of the basals was due to that cause only, genera such as *Eucalyptocrinus*, *Coccocrinus*, *Mycocrinus*, *Dolatocrinus* and *Corymbocrinus*, which have no anal plates in the calyx, should have very regular basals, while in fact *Eucalyptocrinus* has the same basal arrangement as *Melocrinus*, *Dolatocrinus* as *Hexacrinus*, *Corymbocrinus* as *Abacocrinus*, the last named of which all possess anal plates. It is also well known that in *Platycrinus* and the Blastoidea, and all other genera with three unequal plates in the basal ring, the smaller plate is always located to one side, not posteriorly, and it is difficult to understand how in *Haplocrinus* the asymmetry of the calyx could be attributed to an anal plate, or to the anal opening, when the latter penetrates the very top of the so-called "orals." We admit that the dorsal cup is more frequently asymmetrical in Palæocrinoidea than in Neocrinoidea, but exceptions are so numerous that we cannot attach to this point the importance that Carpenter does, who considered the symmetry, or want of symmetry, to be the best distinction between the two groups. We believe the condition of the mouth, and that of the oral surface generally, is of much greater importance, and proves to be a more constant character than any of those to which attention has been directed. Carpenter thinks *Coccocrinus* forms an exception to this rule, which he regards to be in the condition of the Neocrinoid genus *Holopus*, and that consequently its mouth was exposed. If this were true, we should not hesitate a moment to refer that genus to the Neocrinoidea, as nothing would be left to make it a Palæocrinoid, not even the asymmetry.

Carpenter denies that interradials are present as a rule in

Palæozic Crinoids, and he, therefore, does not attach to these plates the value which we think they deserve. According to our interpretation they are present in all Palæocrinoids, but absent or incompletely developed in the Neocrinoidea. By means of the interradials the two groups differ essentially in their larval state; the whole ventral surface of the Neocrinoid larva is covered by the orals, but in the Palæocrinoid larva the interradials physiologically take their place, and the orals or their equivalent is subtegminal. The indistinct calyx interradials, which appear for a short period in the Pentacrinoid larva, became resorbed before taking any prominent part in the formation of the calyx, while the interradials of all Palæocrinoids are well defined and permanent plates. It is possible that the interradials of the Encrinidæ were similarly resorbed shortly before the Crinoid reached maturity, but they were evidently well developed in their earlier life, as we may judge from their affinities with the Cyathocrinidæ and Poteriocrinidæ, and this, principally, has induced us to refer them to the Palæocrinoidea.

We propose the following definitions of the two groups:—

PALÆOCRINOIDEA Wachsmuth.

Crinoids with irregularly pentamerous calyx; plates united by suture or articulation. Base monocyclic or dicyclic. Basals and underbasals variable in number. First radials rarely in lateral contact all around, two of them often separated by an anal plate, and sometimes all of them by interradials. The succeeding plates of the rays are free or become incorporated into the calyx. Arms more frequently biserial than uniserial. There is always at least one interradial to each side which is located ventrally, but when there are a number of them, dorsally and ventrally. The interradials extend to the summit plates or cover them, occupy the greater portion of the ventral surface, and either form a vault over the perisome or support the perisome; in either case, however, mouth and disk ambulacra are completely closed. The summit plates are substantially a repetition of the plates in the calyx. They consist of an undivided plate which represents the basals; of the proximals or interradials and anals; and frequently of radial dome plates.

NEOCRINOIDEA Carpenter.

Crinoids with regularly pentamerous calyx, without interradial or anal plates (*Thaumatocrinus* excepted). Underbasals rarely

well developed, being either rudimentary or absent. Basals five, exceptionally three. Radials perforated, and generally united to succeeding plates by a muscular articulation. Rays simple or dividing; the lower arm joints frequently connected laterally by perisome. The first axillary plate generally the second joint after the first radial; arms uniserial. Ventral surface completely occupied by actinal structures, either simply membranous or paved with irregular plates; traversed by the ambulacra, which have open food grooves. Orals five; always represented in the larva, but frequently resorbed in the adult; at first in lateral contact, but afterwards separating so as to open out the tentacular vestibule, and expose the mouth.

Classification.

The "Stalked" Echinoderms, by which we understand the Crinoidea in their widest sense, have been regarded by some writers as constituting an independent class, by others as an "order" of the class Echinodermata. The latter view, which has been adopted by most of the later European systematists, was somewhat modified in the classification of Dr. P. H. Carpenter, who ranks the Stalked Echinoderms under the name "Pelmatozoa" as a "branch" of the "phylum" Echinodermata, and he makes the Crinoidea—*sensu str.*—and the Cystidea and Blastoidea, full classes, of equal rank with the Holothurians, Echinoids, Asteroids and Ophiurids.

The name Pelmatozoa, as stated by Carpenter (Chall Rep., p. 193), was introduced by Leuckart in an essay published in 1848, and more fully discussed in 1865, in his "Bericht über die wissenschaftlichen Leistungen in der Naturgeschichte der niederen Thiere." In the latter paper he subdivides the Echinodermata into three groups: the Pelmatozoa, to include the Stalked Echinoderms, *i. e.*, Crinoidea in the broadest sense; the Scytodermata, to embrace the Holothurians; and the Echinozoa, under which he placed the Urchins, Starfishes and Ophiurans.

That the Stalked Echinoderms and Holothurians are more distinct from each other, and from the three groups for which Leuckart proposed the name Echinozoa, than these are among themselves, cannot be denied, but it is questionable whether it is necessary or even desirable to express this in the classification, any further than by placing in juxtaposition the nearest allied groups. Too many subdivisions encumber the classification, and

as long as the Scytodermata and Echinozoa of Leuckart are not accepted, we think it unnecessary to establish a branch for the Pelmatozoa. In principle, however, we agree with Carpenter, and admit that the "Pelmatozoa" differ very essentially "in the presence of a stem, and in the consequent departure from the ordinary habits of an Urchin, Starfish or Holothurian. Whether sessile or provided with a stem, the Crinoid lies on its aboral surface instead of creeping about mouth downwards in search of food" (Chall. Rep., p. 193), and they differ also in having no locomotor organs in connection with the ambulacral system (Ibid., p. 188). All this, however, we think is sufficiently expressed by giving the Pelmatozoa the rank of a class, and placing them at the end of the list.

In our opinion there is no doubt that J. S. Miller proposed the name Crinoidea to designate exclusively the brachiate Crinoids, for he stated in his description (A Nat. Hist. Crin., p. 7), that "there proceed from the upper rim of the cup-like body five articulated arms, divided into tentaculated fingers," and among the species which he refers to them there is neither a Blastoid nor a Cystid. Unfortunately, however, later writers have used the name in a twofold sense, designating thereby the class and one of its subdivisions, until lately Zittel, in his Handb. der Palæontologie, to remedy this, proposed the name "Eucrinoidea" for the "Brachiata" *i. e.*, Crinoidea, *sensu str.*, and "Crinoidea" to take the name of the class, an arrangement which has since been accepted by De Loriol. To conform to Miller's idea, the new term should have been given to the class, and not to the subdivision. But as Leuckart had already proposed the collective name "Pelmatozoa," which has priority, and is a more appropriate term than Crinoidea, Zittel's scheme need not be discussed.

Carpenter has placed the Blastoidea and Cystidea on a level with the Crinoidea, making all three distinct classes, a rank to which we think they are not entitled. The three groups, according to our views, are mere modifications of the same plan which, so far as known, originated in the Cystidea, and of which the Blastoidea and Crinoidea are mere offshoots. The latter group, but especially the Blastoidea, are linked together with the Cystidea by such easy transitions, that among the earlier types it is difficult to draw any clear line of demarkation. We are unable to point out a single character that is not found exceptionally in

one of the other groups. We do not except the calicine pores or the pectinated rhombs, which are regarded as characteristic of the Cystids, nor the lamellar tubes beneath the ambulacra, which were thought to be restricted to the Blastoids. Even jointed arms occur in many Cystids, and in some of them they are connected with the radials in a similar manner as in the Crinoidea.

We do not wish to enter upon a discussion of the structural peculiarities of the Cystidea and Blastoidea, and, if we allude to them here, it is only to illustrate their close affinities with one another, and with the Palæocrinoidea. *Asteroblastus*, judging from the calyx, is a Cystid, but it has Blastoid ambulacra, Blastoid pinnules, associated with ambulacral and calicine pores. The same structure occurs in (?) *Agelacrinus Pusirewskii* Hofmann. On the other hand, the Blastoid genus *Codaster* has neither spiracles nor ambulacral pores; its hydrospires open out like those of certain Cystidea, and they do not underlie the ambulacra, but are placed alongside of them. *Codaster* was referred by Billings and Zittel to the Cystidea, but is now generally recognized as a Blastoid. *Stephanocrinus* has been variously described as a Crinoid, Blastoid and Cystid. As admitted by Carpenter, it has probably no hydrospires, and so far as known no calicine pores nor pectinated rhombs, but it possesses long Crinoid-like brachial appendages. *Caryocrinus*, which has been very generally regarded as a Cystid, has segmented pinnule-bearing arms like a Crinoid, and these are attached to the radials, but it has calicine pores, and numerous hydrospires along the inner floor of the calyx. *Porocrinus* has a calyx and arms like a Cyathocrinoid, but calicine pores like a Cystid. *Hybocystites* was described by Wetherby as a Cystid; by Carpenter as a transition form between Crinoids and Blastoids, but nearer the latter; while we consider it a Crinoid. Its arm structure is that of a Cystid, but it has apparently neither calicine pores, rhombs, nor lamellar tubes. The Crotalocrinidæ and Eucalyptocrinidæ probably have hydrospires within the calyx, *Cupressocrinus* and *Symbathocrinus* probably hydrospires underneath the ambulacra, and both have segmented arms.

These few examples, to which others might be added, will sufficiently show that neither the Blastoidea and Cystidea, nor the Crinoidea proper, form primary divisions like the Urchins, Starfishes or Ophiurans, but constitute subordinate groups of the

Pelmatozoa. Carpenter admits on p. 191 the close affinities between the Cystids and Blastoids, but the Crinoidea he takes to be a well-defined group " by having segmented arms attached to the radials, contrary to the Cystids and Blastoids in which there are either no arms at all, or structures of an entirely different nature from those of the true Crinoids." We have already directed attention to *Caryocrinus* and *Porocrinus* as having well-developed arms, similar to those of *Hybocrinus*, and also calicine pores. If we were to make the division between Crinoids and Cystids upon the arm structure, and did not make the calicine pores the principal distinction between those groups, we would also have to place among the Crinoidea *Comarocystites*, which has not only segmented arms but even pinnule-like appendages. Neither could we leave out *Glyptocystites* and *Pleurocystites*, in which the arms are long and lined with well-defined covering plates.[1]

Burmeister (Zoonomische Briefe, Leipzig, 1856, vol. i, p. 243) divided the " Crinoidea " into Anthodiata, among which he included the Cystidea and Blastoidea, and " Brachiata " with Tessellata, Articulata, Costata and the genus *Holopus*. This arrangement, leaving out the Costata, which probably are not Pelmatozoa at all, seems to us a very good one, and we find it convenient to adopt his divisions as " subclasses," substituting, however, for Burmeister's name Brachiata, Miller's older name Crinoidea. This enables us to discriminate between Palæocrinoidea and Neocrinoidea on the one side, and Cystidea and Blastoidea on the other, which, as we have stated, are more distinct from one another than the groups which we place under them. To make the Anthodiata and Crinoidea separate classes, on a level with the Urchins, would give to them too much importance. We doubt if Carpenter will claim them to be anything like as distinct groups as the Ophiurids and Starfishes, which by some systematists were regarded as mere subgroups of the

---

[1] The Cystidea have never been properly defined. They form in our opinion an assemblage of several groups of equal rank with the Blastoidea. S. A. Miller pointed out in the Cincinnati Journal of Nat. Hist., Dec. 1882, the Lichinocrinoidea and Agelacrinoidea as orders of the Crinoidea ; the latter name, however, must be changed to "Edriasterida," as this has priority. It was proposed by Prof. Huxley in his classification of animals, London, 1869, p. 130 (Carpenter).

Stellerites. These, however, differ essentially in their mode of development, which can hardly be claimed for the Anthodiata and Crinoidea. We can only say of them that, as a rule, in the former the organs generally were contained within the calyx, whereas in the Crinoidea the generative and respiratory apparatus is almost entirely confined to the arms, and probably neither Blastoids nor Cystids had appendages united by paired muscular bundles. The Palæocrinoidea form parallel groups with the Blastoidea, both being descendants of the Cystidea; while the relations of Palæocrinoidea and Neocrinoidea are similar to those of Palæocrinoidea and Cystidea, and Cystidea and Blastoidea; but the Neocrinoidea, although they are of later descent, are equally well defined. In making these four groups orders of the Anthodiata and Crinoidea respectively, we place at the head of the list the Cystidea, as being the typical form, the Blastoidea next, and at the opposite end the Palæocrinoidea and Neocrinoidea.

In correspondence with Dr. Carpenter he has admitted that his classification tends to give an expression of well-marked differences between Crinoids, Cystids and Blastoids, which, as he stated on p. 191 of his Report, do not exist between the two latter, and we are authorized to state that he concurs with us in re-establishing Burmeister's Anthodiata and Brachiata, as we have practically done, the former to include as "orders" the Cystidea and Blastoidea, the latter the Palæocrinoidea and Neocrinoidea. We believe, therefore, that there is very little difference between us on this point.

Various other classifications have been proposed by different writers, for which we refer to the Challenger Report, pp. 186–196. The following classification will be adopted by us, viz.:—

Phylum, ECHINODERMATA.

Class, PELMATOZOA.

Subclass I, *Anthodiata*.	Subclass II, *Crinoidea* (*Brachiata*).
Order 1, CYSTIDEA, ETC.	Order 3, PALÆOCRINOIDEA.
Order 2, BLASTOIDEA.	Order 4, NEOCRINOIDEA.

Class, PELMATOZOA.

Definition.[1]—Echinoderms which are fixed either permanently

[1] This and the succeeding definition is taken from Carpenter (Chall. Rep., pp. 186), with a slight alteration in the first one which is indicated by italics.

or temporarily by the middle of the aboral surface. A jointed stem containing a neurovascular axis is usually present, but may be lost when maturity is reached; or in the case of a few sessile forms, remain altogether undeveloped. The apical system consists of a dorsocentral plate, basals and radials, with the frequent addition of underbasals and interradials. These plates form a cup, which either simply supports or more or less completely encloses the visceral mass, and often bears jointed appendages, the arms and pinnules.

An oral system, to some extent a repetition of the plates in the apical system, consisting of basals, radials and interradials, covers the peristome, but may be altogether resorbed, or be restricted to basals only. The anus either is located within the calyx, and surrounded by abactinal plates, or forms a part of the oral surface.[1]

The water vascular ring does not communicate directly with the exterior, and the lateral branches of the radial vessels (when present) are respiratory, but not locomotor in function.

Subclass, *Crinoidea.*

Definition.—Pelmatozoa, in which the radial plates of the calyx bear more or less branching arms. These consist of segments which are articulated by means of muscles and ligaments, and in most cases bear similar jointed appendages, the pinnules. The nervous system consists (1) of a central organ situated in the calyx, and fibres extending from it through the skeleton of the stem, arms and pinnules; (2) of a circumoral ring and radial extensions which are in close relation with the ciliated epithelium of the ambulacral grooves. These are more or less extensively distributed on the ventral surface of the disk, arms and pinnules; and are bordered by groups of tentacles which alternate on opposite sides. When they are absent, the radial water vessels give off no tentacular branches. The water vascular ring opens by five or more water tubes into the body cavity, which itself communicates with the exterior by a corres-

[1] Carpenter's version: "An oral system, consisting of a central plate (orocentral) and five orals, is developed above the peristome of the larva to a very variable extent, and may be either altogether resorbed, or reach a high degree of importance by the appearance of additional plates so as to form a vault or *tegmen calycis.* The anus is situated on the oral surface, which may be bare, or more or less covered by calcareous plates."

ponding number of water pores. The mouth is central, except in a *few genera*, and the anus subcentral or excentric. The genital glands are lodged in the lower parts of the arms, but are usually fertile only in the pinnules.

THE SUBDIVISIONS OF THE PALÆOCRINOIDEA.

Among the Palæocrinoidea we recognize three great divisions, which on the whole correspond to our former groups, Sphæroidocrinidæ, Ichthyocrinidæ and Cyathocrinidæ. These groups, which are divisible into definite subgroups, will be ranked by us as suborders of the Palæocrinoidea, and the subgroups as families. The three suborders, for which we have proposed the names *Camarata*, *Articulata* and *Inadunata*, are distinguished from one another principally by the mode of union among the calyx plates, and the condition of the arms as to whether their lower plates constitute a part of the calyx, and as such enclose the visceral cavity, or form parts of the free arms. These groups are not only well defined in nature, as shown by the fact that they are so readily recognized, but they are also most convenient for all descriptive and comparative work.

When we first defined the three groups (Rev., i and ii), we laid the greatest stress upon the construction of the ventral surface, which, as we stated, offered most excellent characters for their separation; but as the modifications which take place among them, to a large extent, result from the conditions of calyx and arms, we regard the structure of their ventral side as of subordinate rank. This necessitates a re-description of those groups, especially as our present views upon the ventral plates generally differ essentially from those previously held by us.

We have stated that the so-called "orals," upon which the "Cyathocrinidæ"—the Inadunata of our new classification—were at that time principally founded, are interradials, which attained their ventral position by being in lateral contact, in place of resting laterally against the lower arm plates. The construction of the ventral surface in the earlier Inadunata thereby became fundamentally identical with that of the "Sphæroidocrinidæ," except that the latter attained subsequently a larger number of interradials. In the later Inadunata the ventral structure is very different; indeed, so much so that the two sections according to our former views should have been distinctly separated. This we

had contemplated, but we encountered great difficulties, as the two forms run very closely from one into the other. Even the ventral sac, the best distinguishing character, undergoes all possible modifications. It dwindles down to almost nothing in some of them, and its porous nature is sometimes very indistinctly developed or even unrepresented. We regard these modifications, as they occur in palæontological times, as representing various stages of development in the history of this group, and as good generic characters, but do not attach to them the importance we did before. We have, however, placed the genera in which a ventral sac is developed as a group by themselves, to separate them from those in which it is absent. The latter group, which represents the larval form, will be designated by us as "*Larviformia*" the former as "*Fistulata.*"

Instead of the name Sphæroidocrinidæ, which is objectionable for several reasons, we propose to use *Camarata*, under which we have placed several additional groups. To the *Articulata* (nobis, not Müller or Miller), which we restrict to the *articulated Palæocrinoidea*, we refer the Ichthyocrinidæ and Crotalocrinidæ. If there is any objection to re-establishing Müller's name, which has been generally discarded, we might change Articulata into "Articulosa." We think, however, we are fully entitled to adopt the former, as the Crinoids which we refer to them are true Articulata in Müller's sense. We place the Camarata, which we regard as the typical form of the Palæocrinoidæ, at the head of the list, the Articulata next, and the Inadunata, which in some respects approach the Neocrinoidea, at the opposite end.

The CAMARATA embrace all Palæocrinoidea in which the plates of the test are solidly united by suture, and in which the lower arm plates are incorporated by means of interradial plates so as to form a part of the calyx. The underbasals are frequently undeveloped. The basals of monocyclic genera are variable in number, five being the exception. The primary radials consist generally of three plates to each ray, rarely of two or four. There is always at least one secondary radial, which may give off the free arms or support others, and frequently radials of higher orders. Interradials numerous, or not less than two; the first one resting upon the sloping upper sides of the first radials, or alternating with them. The interradials, together with the interaxillaries and anal plates, separate the rays and their sub-

divisions, and cover the greater part of the ventral surface up to the summit plates, or the whole of it including the latter. The free arms are simple or branching, and with a few exceptions biserial, uniserial only in their immature state, permanently only in a few Silurian genera. The articulation of the arms is primitive, and dorsal canals have never been observed. All have pinnules, which as a rule are closely folded together. The anus is surrounded by solid plates, suturally connected; its position is excentric, except in the Eucalyptocrinidæ.

The summit plates are largely developed, and consist in all Carboniferous, and in most of the Devonian genera, of an undivided oral plate, proximals, and frequently one or more radials; in most of the Silurian forms, however, of orals only, and even these may be covered by interradials. The disk is subtegminal, but sometimes the covering pieces enter the outer surface, when they take the condition of surrounding plates. The Camarata have small openings along the brachial zone, by means of which the water for respiration entered the body.

To the ARTICULATA we refer all Palæocrinoidea in which the test is pliable. The calyx extends to the lower arm joints, and the plates are united by articulation, and not by suture. Underbasals are always represented; they are small, being frequently covered by the column, and consist of either three or five plates. The number of primary radials varies from two to seven or more, and also the number of the higher orders is very variable. The radials of different rays are either in contact laterally or connected by the help of interradials. In the former case, frequently, a smaller number of radials alternates with a larger one, and the plates of one ray rest with their upper sloping sides against the lower sloping sides of their fellows of adjoining rays, or *vice versa.* When the radials are separated by interradials, these either extend to the basals, or rest against the upper sloping sides of the first radials. In some cases, however, the interradials are restricted to the ventral surface. The form of the calyx varies from almost strictly pentamerous to bilateral symmetry, but it sometimes becomes irregular, owing to the interposition of an azygous plate. Some species have no anal plate dorsally. The radial and arm plates are united horizontally by muscles and ligament, or perhaps in some cases by ligament only. The lateral face of the radials and those of the interradials are provided with deep ligamental fossæ. The arms are closely folded together,

and sometimes connected laterally by a membranous substance. The ventral surface, so far as known, is composed of interradial plates; it forms a pliable vault, which extends to the free rays, and probably covers not only the disk, but also the summit plates. The Crotalocrinidæ have no anambulacral pieces, but possess hydrospires within the calyx.

The INADUNATA are subdivided into *Larviformia* and *Fistulata*. They include all Palæocrinoidea in which the arms are free from the first radials. Their calyx is comparatively small; composed exclusively of basals, frequently underbasals, five radials, five interradials, and one or two azygous plates. The proximal ring of plates, whether basal or underbasal, is composed of five, or less frequently, three plates. The radials are laterally connected except at the posterior side, where they are separated by an azygous and anal plate, if these have not been resorbed. The presence of the azygous plate gives to the calyx a very irregular outline. The interradials are located ventrally; they rest against the upper ends of two adjoining radials, and join along their lateral margins.

The ventral covering of the LARVIFORMIA consists of comparatively few pieces, among which generally the combined muscle plates form a conspicuous part. The central space is covered either exclusively by interradials, or these enclose an oral plate, which in some of the higher forms is surrounded by proximals. The disk is subtegminal in place of being extended into a lateral sac. The anal opening either penetrates the interradials, or is placed intermediate between two radials or their appendages. Respiration took place by pores along the arm furrows, which probably communicated with hydrospires.

In the higher organized FISTULATA the perisome is partly or wholly exposed, the interradial plates either cover the perisome, or this partly covers them. In the latter case the summit plates may be resorbed, in the former they are largely represented; but in either case portions of the disk penetrate the calyx posteriorly by passing out through the anal opening. These portions form either a balloon-shaped or a tubular sac, composed of well-defined plates, closed at the end, but perforated over the surface by pores along the suture lines; the pores penetrating the lateral edges of the plates. Respiration took place by means of the pores along the perisome.

PHYLUM, *ECHINODERMATA.*

CLASS, PELMATOZOA.

SUBCLASS, Crinoidea.

ORDER, PALÆOCRINOIDEA.

SUBORDER, CAMARATA.

The Camarata embrace the Platycrinidæ, Actinocrinidæ and Rhodocrinidæ, which in Part II we grouped together under the name Sphæroidocrinidæ, and also the Acrocrinidæ and Calyptocrinidæ, which are here described.

In a paper on *Glyptocrinus* and *Reteocrinus*, Amer. Journ. Sci., vol. xxv, April, 1883, we intimated on p. 267, that we might find it advisable to place *Glyptocrinus*, *Reteocrinus* and allied genera in a family by themselves. This had been done by Zittel, and has since been adopted by S. A. Miller, under the name of Glyptocrinidæ. Zittel included in this family *Glyptocrinus*, *Glyptaster*, *Thylacocrinus*, *Cupulocrinus*, *Lampterocrinus*, *Eucrinus* and *Sagenocrinus*, genera all having well developed underbasals, with the exception of *Glyptocrinus*, in which they were said to be rudimentary. Miller's Glyptocrinidæ contain *Archæocrinus*, *Cupulocrinus*, *Glyptaster*, *Lampterocrinus*, *Reteocrinus* and his proposed genus *Gaurocrinus*, all having underbasals, and *Glyptocrinus*, *Xenocrinus* and his *Compsocrinus* and *Pycnocrinus*, which he described as having but one ring of plates below the radials.

The presence of underbasals has been very generally considered a good family distinction, and it has always been a question of doubt with us whether we were justified in departing from this rule by placing *Glyptocrinus* and *Xenocrinus*, in which underbasals were said to be absent or indistinctly developed, in the same group with *Reteocrinus* and *Archæocrinus*, in which those plates form a more or less important part. The genera which Miller has grouped together, and a few more, agree remarkably in general aspect, but they differ not only in the matter of underbasals, in the number of basals, but also very materially in the disposition and form of their interradial plates.

Glyptocrinus was originally described as possessing no underbasals. Hall afterwards discovered minute pieces enclosed by the ring of plates which he had previously designated as basals, and which he now called subradials, taking the small inner pieces

for the true representatives of the basals. The presence of these small pieces was also acknowledged by Meek and ourselves, but Meek hesitating to call them basals, applied the name "sub-basals;" while we took them to be rudimentary underbasals, and as such they have been described in Part II of the Revision, and in our April paper.

We have stated elsewhere, that in all Crinoids having basals only, the column, when pentagonal, has its angles directed radially, the radii of the pentapetaloid or five rayed columnar canal interradially, and that the opposite is the case in all species, throughout all Palæocrinoidea in which underbasals are present. Applying this rule to *Glyptocrinus* and allied genera, we find that every species referred by us to *Glyptocrinus*, is without underbasals, and that all those, with one or two exceptions, which we placed under *Beteocrinus*, have underbasals. The exceptional species are *Glyptocrinus Richardsoni* Wetherby, of which we speak later on, and Meek's *Glyptocrinus Baeri*, which we found to be a *Xenocrinus*, having four basals and a subquadrangular column; but, like *Xenocrinus* and *Mariacrinus*, a pentangular axial canal, its angles directed strictly interradially. By carefully grinding off the base in *Gl. decadactylus*, and in several other species, we have become satisfied that the pieces which have been designated by Hall, Meek and ourselves heretofore, respectively, as basals, sub-basals, and rudimentary underbasals, form no part of the calyx, but constitute the uppermost portion of the column, which in this genus rests within a remarkably deep, funnel-shaped concavity.

Among the species arranged by Miller under *Glyptocrinus*, and which were said to have no underbasals, are *Glyptocrinus Richardsoni* Wetherby, and *Gl. Pattersoni* Miller. In Rev., Part II, and subsequently in our paper in the Amer. Journal, these species were placed under *Reteocrinus* Billings. In neither one of them have underbasals been observed, although these plates may be present, hidden beneath the column, as in the case of many Rhodocrinidæ and Poteriocrinidæ. The species differ, however, very materially from *Gl. decadactylus* and allied species without underbasals in the distribution and position of their interradial plates, which are irregularly arranged, and rest upon the five basals, exactly as they do in *Reteocrinus stellaris* and in *R. O'Nealli*, which, contrary to the other species, have well developed underbasals. The case is similar in *Xenocrinus penicillus* Miller, only that in

this species underbasals are known to be absent, and they have four in place of five basals. Any difference in the number of basals has been generally considered a good generic distinction, and this makes *Xenocrinus*, undoubtedly, a good genus. But in which group shall we place it? Together with *Reteocrinus* or *Glyptocrinus?* Together with species in which the interradials rest upon the basals, and which have well developed underbasals, or with species destitute of underbasals, and with their interradials, as in *Glyptocrinus*, resting upon the first radials?

In Part II we maintained that, as a rule, the presence or absence of underbasals should be considered of more than generic importance, and this we made the principal distinction between Actinocrinidæ and Rhodocrinidæ. We pointed out, however, that in these families there are several genera, among the earlier types, which are closely connected by transition forms, and shade almost imperceptibly from one into another. We even thought it possible that species of the same genus might possess underbasals in a rudimentary way, while those plates might be totally absent in others. This is not confirmed by our later investigations, but it is nevertheless by no means an easy task to separate some of the earlier genera upon this character, as there are frequently other important features by which they are much more closely connected with other groups. In proof of this we need only refer to *Glyptocrinus Richardsoni*, provided this really possesses no underbasals, as Miller asserts, and to *Reteocrinus O'Nealli*, in which they are very conspicuous. As the two species are almost identical in every other respect, it would seem doubtful policy to refer them to distinct families upon this character alone. S. A. Miller evidently experienced the same difficulty, for his Glyptocrinidæ include genera of both forms. Zittel, De Lorial, and all preceding writers, make the presence of underbasals a full family distinction, and all their Glyptocrinidæ and Rhodocrinidæ are said to have underbasals.

Diversities in the distribution of the interradial plates of the calyx have been generally taken to be of minor morphological importance; but at the same time they have been considered good characters for distinguishing genera. S. A. Miller alone has placed in the same genus species, which in this respect show the greatest possible contrast. It is, however, rather singular that he applies this rule only to the " Glyptocrinidæ," while in other

groups he considers such difference to be at least of generic importance, and what is more singlar, he even constructed thereon a whole family. His Melocrinidæ differ from his Actinocrinidæ mainly in having all five interradial spaces arranged almost uniformly, and they generally have four basals. That Miller did not make the number of basals the distinctive character, is very evident, or he would have arranged his *Xenocrinus penicillus* and "*Compsocrinus*" *Harrisi* among the Melocrinidæ. On the contrary, he placed these species under distinct genera; while he referred *Glyptocrinus decadactylus* and *Reteocrinus Richardsoni* to the same genus, although these two differ in exactly the same way as the two former species.

One is curious to know upon what ground Miller based his Glyptocrinidæ. Not upon the underbasals, nor upon the relative number of basals; neither upon the ridges along the radials, for these are absent in *Cupulocrinus* and *Lampterocrinus*, and certainly not upon the ornamentation, which he asserts does not hold good even among those genera. They are united by no single character, and since it has been clearly proved that *Glyptocrinus* has no underbasals, this genus no longer falls within the Rhodocrinidæ, which were fundamentally based upon the presence of those plates, and must be referred to the Actinocrinidæ. That *Glyptocrinus* was in many respects closely allied to the Actinocrinidæ, subdivision Melocrinites, has been shown already in Part II, and several species were at first described under *Glyptocrinus*, which we have since referred to *Mariacrinus*. Among these is *Gl. Harrisi*, for which Miller lately proposed the genus *Compsocrinus*. The generic definition of *Compsocrinus* is partly based upon inaccurate observation, for the interradials of all five sides rest upon the edges of the first radials, and not one of them upon a basal, as figured by Miller in his diagram pl. 11, fig. 4, a.

It has been stated in Part II, p. 185, that the interradials of all known Actinocrinidæ, except sometimes those of the azygous side, rest upon the first radials, and this is the case in *Glyptocrinus* and "*Compsocrinus*." We find an apparent exception to this rule, if we make the absence of underbasals the controlling family character, in the genus *Xenocrinus*, and perhaps in *Glyptocrinus Richardsoni* and *Gl. Pattersoni*, in which underbasals have not been observed. The two latter species agree in all essential particulars with *Xenocrinus*, in which we include not only Miller's

type, but also *Glyptocrinus Baeri* Meek. These two species, however, have four basals, while the two former ones have five. Equally close are the affinities with *Reteocrinus*, which has well defined underbasals. *Xenocrinus*, *Reteocrinus*, and *Glyptocrinus Richardsoni*, which we make the type of our new genus *Canistrocrinus*, agree in the following features: The plates of the five main rays and their branches are formed into tube-like ridges along the middle, with lateral extensions to meet the interradials. The interradial areas are deeply depressed; composed of numerous minute, irregularly arranged plates. They abut against the basals and isolate the first radials to their full length. The azygous interradius is divided by a conspicuous, rounded ridge, composed of strong, comparatively large plates, longitudinally arranged, which slightly decreasing in size, extend out to the subcentral anal opening.

Reteocrinus, *Xenocrinus* and *Canistrocrinus* constitute a natural, well defined group, and it seems to us impracticable to separate them upon the ground that some of the species possess underbasals. The lateral separation of the first radial plates distinguishes them from all Actinocrinidæ, and this, according to P. Herb. Carpenter,[1] "is a fact of considerable importance in Crinoid morphology; but in this very character they approach somewhat the Rhodocrinites, in which, as a rule, the first interradials all around meet the basals. Among the Rhodocrinites, however, the lower interradials are perfectly regular plates, their position is fixed, and they are succeeded by equally regular pieces. Whether such widely different plates, as here represented, can be compared with each other, is very doubtful, and this seems to have been the opinion of Carpenter, who intimates that the irregular small pieces of *Reteocrinus* can hardly be regarded as the complete morphological equivalents of the larger and more regular single interradials which occur in the Rhodocrinidæ." That these irregular interradial plates occur in none of the later groups of the Palæocrinoidea, but only in the very earliest Silurian types, and under decidedly similar conditions, in species with and without underbasals, points clearly to the conclusion, that those genera constitute a little group by themselves, and we think this justifies us in

[1] On a New Crinoid from the Southern Sea by P. Herb. Carpenter, M. A., Philos. Trans. of the Roy. Soc., Part III, 1883.

recognizing them as a distinct family, which we propose to call *Reteocrinidæ*.

Now, having referred the genus *Glyptocrinus* in its typical form, and "*Glyptocrinus*" (*Compsocrinus*) *Harrisi* Miller, = *Mariacrinus Harrisi*, to the Actinocrinidæ or their allies, *Reteocrinus*, *Xenocrinus*, and our new genus *Canistocrinus* to the Reteocrinidæ, there remain for consideration among species with underbasals, or Rhodocrinidæ, as they were previously called, two other groups:

(*a*.) Species, in which all five primary interradials meet the basals, forming a ring of ten plates with the first radials.

(*b*.) Species, in which the first anal plate only rests upon the basals, the interradials upon the edges of the first radials. The first group comprises the genera: *Archæocrinus*, our new genus *Rhaphanocrinus*, *Lyriocrinus*, *Rhipidocrinus*, *Thylacocrinus*, *Anthemocrinus*, *Rhodocrinus*, and *Ollacrinus*; the second *Glyptaster*, *Dimerocrinus*, *Ptychocrinus* and *Lampterocrinus*. The former group agrees with our subdivision *Rhodocrinites*, except *Archæocrinus*, which we had previously arranged under Glyptocrinites; the latter corresponds with our former Glyptasterites.

It might be as well, perhaps, to let these groups remain as subdivisions of the Rhodocrinidæ; but, as it is desirable that the families proposed by various authors in the different classifications should be made to correspond as far as possible, we follow Zittel, and rank them as full families. The first, as embracing the typical genus, will be *Rhodocrinidæ*. Zittel's name, Glyptocrinidæ, however, cannot be used for the other group, since it is known that *Glyptocrinus* has no underbasals. We propose in its place the name *Glyptasteridæ*, *Glyptaster* being one of its most characteristic types.

These divisions are substantially in conformity with the views of Carpenter, expressed in his paper on *Thaumatocrinus*, p. 929. He approves Zittel's division into Glyptocrinidæ and Rhodocrinidæ, but acknowledges at the same time "that *Glyptocrinus* has decided affinities with the Actinocrinidæ." His views upon the irregular plates of *Reteocrinus* have already been quoted. The rounded ridges along the radials, as they appear in *Reteocrinus* and *Xenocrinus*, are more than mere ornamentations. They seem to have contained tubular passages which, perhaps, may represent the axial canals, while the more angular ridges of *Glyptocrinus*, *Glyptaster*,

etc., must be considered simply as an ornamentation of the calyx. They represent, as stated by Carpenter, "a character of altogether minor importance as compared with the morphological difference between the lateral union and the isolation of the radials."

In Part II we have placed under *Actinocrinidæ* all Crinoids without underbasals, in which the interradial plates are connected by suture, and the basals support the radials, and frequently a large anal plate, but none of the regular interradials. This excluded the allied genus *Acrocrinus*, in which basals and radials are separated by a large number of accessory pieces. We excepted also the *Calyptocrinidæ* with *Eucalyptocrinus* and *Callicrinus*, which differ essentially in their vault structure, and the *Barrandeocrinidæ* for other reasons to be explained hereafter.

The Actinocrinidæ, as they were defined by us, comprise a well-defined natural group; and we find it difficult to subdivide them, unless it be upon the presence or absence of an anal plate in line with the first radials, *i. e.*, the bilateral symmetry of the one group as contrasted with the more or less pentamerous symmetry in the other. In making this division, we place the Stelidiocrinites and Melocrinites with their almost regular symmetry in the one group, and the Agaricocrinites, Periechocrinites, Actinocrinites and Batocrinites in the other, the former as *Melocrinidæ*, the latter as *Actinocrinidæ*.

Rœmer, Lethæa Geogn., 1855 (Ausg. 3), p. 228, distinguished Melocrinidæ from Actinocrinidæ, the latter on account of their larger azygous interradius, and having three in place of four basals. Zittel partly recognized these groups, but added to the Melocrinidæ *Scyphocrinus* Zenker (not Hall), *Corymbocrinus* and *Abacocrinus*, the latter with an anal plate upon the basals, thus proving that he made the number of basals the distinctive character. He divided our Actinocrinidæ into the families *Briarocrinidæ*, *Carpocrinidæ*, *Dimerocrinidæ*, *Actinocrinidæ* and *Polypeltidæ*.

Our *Platynicridæ* were subdivided into Platycrinites and Hexacrinites, the one with strictly pentamerous symmetry in the calyx, the other bilateral. The two groups are easily recognized, and will be continued, but ranked as families.

The Platycrinidæ have been described by us and other writers as having a single interradial plate in contact with the radials.

This was based upon an incorrect understanding of the plates. That it is not the case in *Platycrinus* is readily seen by our figures on pl. 7. Even the most simple form has three interradials, horizontally arranged, all supported by the first radial plates, and we are convinced that three, or a greater number of plates, are found in all other Platycrinidæ, and all Hexacrinidæ. Wherever we have observed them, the middle plate is larger, and rests upon the juncture of two first radials, the outer ones upon their upper face, meeting laterally the higher radials. The larger number occurs in forms with flattened disc and wide, spreading rays.

The presence of three or more pieces in the first row, which evidently represent the first, second, and perhaps third ranges of interradials in other groups, is morphologically of considerable importance, as it seems to have produced, to a large extent, the structural peculiarities of the two families. It is evident that, owing to the great width of the interradial areas, the succeeding radials could make no connection with the higher interradials, and the rays thereby became isolated, and remained permanently in a more or less embryonic state. Three interradials seem to have been represented also in *Coccocrinus*, as shown in Roemer's figure 5^c of *C. bacca*, although they are not figured in his *Coccocrinus rosaceus*.

We also refer to the Camarata the genus *Barrandeocrinus*. It was made by Angelin, Zittel and De Loriol the type of a distinct family, and this seems to be warranted by its exceedingly strange form, produced principally by the construction of the arms and the arrangement of the plates at the ventral side, although the plates along the dorsal side are arranged similarly to those of the Actinocrinidæ.

The Camarata, according to our classification, fall into ten families:

A. Reteocrinidæ. Base monocyclic or dicyclic. Basals 4 or 5. Radials folded into strong tubular longitudinal ridges along the median line of the plates. Interradial and interaxillary areas deeply depressed; resting upon the basals. They are composed of a large number of ill-formed immovable pieces, which continue to the ventral side, almost completely covering the interpalmar areas, leaving but a small oral plate at the centre. Azygous side wider; divided by a vertical row of rather large

anal plates, which extend to the anal aperture. Arms single-jointed; pinnules strong. Anus subcentral. Column circular or angular.

B. RHODOCRINIDÆ. Base dicyclic. First radials separated from one another by the first interradials, with which they form a ring of ten plates around the basals. Interradial areas composed of well-formed plates, definitely arranged; azygous side scarcely distinct. The interradials in all earlier forms along the ventral side are arranged like those of the Reteocrinidæ, and the proximals are probably unrepresented; but in the later ones proximals are well developed. Anus subcentral. Column circular or obtusely pentangular.

C. GLYPTASTERIDÆ. Base dicyclic. First anal plate resting on the basals, but the first interradials not touching them. Succeeding interradials arranged as in the Rhodocrinidæ. Those upon the ventral surface are sometimes composed of larger plates than in the preceding groups. Anus subcentral. Oral piece and proximals well represented. Column circular or pentangular.

D. MELOCRINIDÆ. Base monocyclic. Basals 3 to 5. Neither anal nor interradial plates touching the basals; the latter in contact with radials only. Interradial areas composed of numerous plates; those upon the dorsal side large, regularly arranged, those along the ventral surface frequently small and irregular. Oral plate generally surrounded by proximals. Anus subcentral. Column circular, rarely angular.

E. ACTINOCRINIDÆ. Base monocyclic. Basals 3, rarely 4. First anal plate resting on basals, the first interradials upon the sloping sides of the first radials. The interradials together with the interaxillaries, anal plates and proximals, form a solid vault over the disk, rarely exposing any of the covering plates. Anus subcentral. Column circular.

F. PLATYCRINIDÆ. Base monocyclic. Basals unequal. Neither anal nor interradial plates touching the basals. First radials extremely large, forming with the basals almost the whole dorsal aspect of the calyx. Second radial small and short, and likewise the higher orders of radials, which in place of being connected by interradials, are formed into lateral branches or free appendages. Interradials three at least, generally more; all located more or less ventrally. The lower range contains no special anal

plate. It consists of from three to five pieces, transversely arranged; the middle one larger, resting upon the sloping upper ends of two first radials; the outer ones abutting against the large primary and smaller succeeding radials. Oral piece large, generally surrounded by proximals, which are very prominent. Covering plates frequently exposed upon the surface. Anus subcentral. Column circular or oval.

G. HEXACRINIDÆ. Base monocyclic. Basals 2 or 3. First anal plate resting on basals, and similar in form to first radials; other plates arranged as in Platycrinidæ. Calyx with similar arm-like extensions. Column circular.

H. ACROCRINIDÆ. Base monocyclic. Basals 2, separated from the radials by a wide belt of small plates, which are arranged in rings around the basals, and occupy the greater part of the dorsal side. Radials 3×5, increasing in size upwards, all isolated laterally. Interradials in two rows; two plates in the lower series, one only in the upper, but the latter larger than the two others. Azygous interradius comparatively much wider, and composed of twice the number of pieces, in addition to the anal plates which form a vertical line. Column circular.

I. BARRANDEOCRINIDÆ. Base monocyclic. Basals 3. First anal plate resting on basals; the interradials upon the sloping upper sides of the first radials. Arms recumbent; united laterally by their pinnules, and together with these forming a solid integument around the calyx. Column circular, large.

J. EUCALYPTOCRINIDÆ. Base monocyclic. The dorsal side uniformly composed of 4 basals, 3×5 primary radials, 2×10 secondary radials, 3×5 interradials, and 1×5 interaxillaries, there being no anal plates. The ventral side consists of 5 large interradials, 5 similar interaxillaries, and 10 small trigonal interbrachial pieces, which form a ring around the dorsal cup, and are succeeded by the summit plates. The summit plates form a neck-like prolongation. They consist of 4 large proximals which constitute a ring by themselves, of two small proximals, and the oral plate. The latter is bisected and pushed to opposite sides by the anal opening, which is strictly central. The plates of the ventral side are formed into 10 compartments for the reception of ten pairs of arms. Column circular.

Family I.—RETEOCRINIDÆ W. & Sp.

RETEOCRINUS Billings.

1881. W. & Sp., Rev. II., p. 191.
1883. W. & Sp.. Amer. Journ. Sci., vol. xxv (April), p. 256–268.
1884. P. Herb. Carpenter, Phil. Trans. Royal Soc., Pt. III, 1883, pp. 919–933.

Syn. Glyptocrinus (in part), Miller; Journ. Cincin. Soc. Nat. Hist., vol. v, April, 1882.

Syn. Gaurocrinus Miller (in part). Ibid. vol. vi, December, 1883.

Reteocrinus is readily distinguished from the other Reteocrinidæ by its well developed underbasals, which extend beyond the limits of the column. From our former list we withdraw *Reteocrinus Baeri*, which is a *Xenocrinus*, and *Reteocrinus Richardsoni* Wetherby, which we make the type of our new genus *Canistrocrinus*.

One more species must be added:

*1883. **Reteocrinus magnificus** (S. A. Miller), **Gaurocrinus magnificus**, Journ. Cincin. Soc. Nat. Hist., vol. vi, p. 230, Pl. 9, fig. 2.—Hudson River gr.—Lebanon, O.

CANISTROCRINUS, nov. gen.

(*κανιστρον*, a willow basket; *κρίνον*, a lily.)

Syn. *Glyptocrinus* (in part) S. A. Miller, 1883, Journ. Cincin. Soc. Nat. Hist., vol. vi., p. 226.

Syn. *Reteocrinus* (in part) W. & Sp., Amer. Journ. Sci., vol. xxv, p. 266.

Generic Diagnosis.—In general aspect closely resembling *Reteocrinus*. The radial ridges strong, tube-like; the interradial spaces deeply depressed. Symmetry decidedly bilateral.

Underbasals perhaps indistinctly developed, more probably altogether absent. Basals five, truncated above for the reception of the lower series of interradials. Primary radials 3×5, of nearly equal size; the first and third similar in form. The ridges of the former branching downward toward the basals; those of the latter upward toward the secondary radials, which they follow until these turn into free arm-plates. Arms branching or simple; composed of single joints, which give off rather strong pinnules.

Interradial spaces composed of numerous small pieces without definite arrangement. The plates rest upon the basals, separat-

ing all five rays from the base up. With the increase of interradials and interaxillaries by age, which seems to have been going on continually in the specimen, more arm-plates, *i. e.* radials, were gradually incorporated into the calyx, involving the proximal pinnules, the plates of which are easily recognized from surrounding interradial and interaxillary pieces by being more prominent. Azygous interradius wider than the four others. It has an elevated ridge, composed of rather large anal pieces, which are longitudinally arranged and have somewhat the appearance of radials. The interaxillary areas are depressed, even deeper than the interradial ones, and they consist of similar plates. The ventral side has not been observed, but was evidently constructed as in *Xenocrinus* and *Reteocrinus*.

We place here the following species :

*1882. **Canistrocrinus Pattersoni** (S. A. Miller), **Glyptocrinus Pattersoni,** Journ. Cincin. Soc. Nat. Hist., vol. v (July), Pl. 3, figs. 2, 2 a. Ibid., vol. vi, Decbr. 1883, p. 226.—**Reteocrinus Pattersoni,** Wachs. and Sp., 1883, Amer. Journ. Sci., vol. xxv, April, 1883, p. 266. Utica Slate, Cincinnati, O.

*1880. **Canistrocrinus Richardsoni** (Wetherby). Type of the genus.—**Glyptocrinus Richardsoni,** Journ. Cincin. Soc., Nat. Hist., vol. ii, Pl. 16, figs. 1, 1 a. W. & Sp., 1881.—**Reteocrinus Richardsoni,** Rev. ii, p. 193; also Amer. Journ. Sci. vol. xxv, p. 266.—Miller, **Glyptocr. Richardsoni,** 1883, Journ. Cincin. Soc. Nat. Hist., vol. vi, p. 226. Hudson River gr., Clinton Co., O.

XENOCRINUS S. A. Miller.

(Pl. 6, fig. 2.)

1881. S. A. Miller. Journ. Cincin. Soc. Nat. Hist., vol. iv.
1881. W. and Sp. Revision ii, p. 184.
1883. W. and Sp. Amer. Journ. Sci., vol. xxv, p. 266.

Xenocrinus is closely allied to *Canistrocrinus*, from which it differs in having four in place of five basals, and a quadrangular column.

Generic Diagnosis.—Base monocyclic. Basals four, forming combined a shallow decagonal cup, which upon five of its sides supports the five radials, and alternately upon each of the five other sides a series of small interradial pieces. This arrangement gives to the basals, owing to their abnormal number, a very irregular form, no two of them being alike. The axial canal in this genus, notwithstanding it has but four basals and a quadranglar stem, is pentangular, its angles directed interradially. In all other respects, including the ventral covering, *Xenocrinus*

agrees with *Reteocrinus* and *Canistrocrinus*, to which we refer for further particulars. We place in this genus also "*Glyptocrinus*" *Baeri* Meek, which we have heretofore referred to *Reteocrinus*, not knowing the construction of its basal portions. It has not only four basals, but fundamentally a quadrangular column, the more or less cylindrical outline being caused by knife-like lateral extensions along the joints ; its cross-section shows the nucleus to be strictly quadrangular.

Geological Position, etc.—Hudson River group of the Ohio valley.

*1872. **Xenocrinus Baeri** (Meek), **Glyptocrinus Baeri,** Amer. Journ. Sci. iii (Ser. 3), p. 260 ; also 1873, Geol. Rep. Ohio, Paleont. I, p. 37, Pl. 2, fig. 1 a, b.—S. A. Miller, 1880, Journ. Cincin. Soc. Nat. Hist., vol. iii, Pl. 7, fig. 4.—**Reteocrinus Baeri** W. & Sp., 1881, Revision ii, p. 193 ; also Amer. Journ. Sci., vol. xxv, p. 266.—**Glyptocr. Baeri** S. A. Miller, 1883, Journ. Cincin. Soc. Nat. Hist., vol. vi, p. 226.—Hudson River gr., Ohio valley.

1881. **Xenocrinus penicillus** S. A. Miller. Type of the genus. Journ. Cincin. Soc. Nat. Hist., vol. iv (April), Pl. 1, fig. 3, and ibid. July), Pl. 4, fig. 6.—Hudson River gr. Waynesville, O.

FAMILY II.—RHODOCRINIDÆ Roemer.

(Emend., Zittel ; emend., W. and Sp.)

ARCHÆOCRINUS W. and Sp.

1881. W. and Sp. Revision, ii, p. 189.
1883. S. A. Miller. Journ. Cincin. Soc. Nat. Hist., vol. vi, p. 217.
Syn. *Lyriocrinus* (S. A. Miller not Hall), 1882, Journ. Cincin. Soc. Nat. Hist, vol. v.

Mr. Walter R. Billings informs us that all the species which we referred to *Archæocrinus*, possess a special anal piece placed between the interradials of the second series. In Part II, p. 190, we erroneously stated that the anal interradius could not be distinguished from the four others, and we are obliged to Mr. Billings for making this correction. We find it confirmed by some interesting specimens which we recently collected from the Trenton limestone near Knoxville, Tenn. Most of these specimens represent Miller's "*Lyriocrinus*" *sculptus*, which was supposed to come from the Niagara group, but which evidently came from a lower horizon. Our specimens were found associated with *Hybocrinus* and other characteristic *Lower* Silurian fossils. *Lyriocrinus sculptus* Miller, or, as we call it, *Archæocrinus sculptus*, is

smaller than any of the Canadian species. It has but one secondary radial, and fewer and larger interradials both dorsally and ventrally, but otherwise agrees well with those types. It probably represents paleontologically a younger stage of that genus, for the arms are free from the first secondary radial. In *Lyriocrinus* the arms proceed upward in a straight line with the walls of the calyx, the arm openings are located ventrally and are arranged at nearly equal distances from each other; while in *Archæocrinus sculptus* the arms extend out laterally in the form of free appendages. In the former the interradials of the ventral side rest against the inner edges of the dorsal cup, the so-called "vault" being perfectly flat; in the latter the vault is elevated and the interradials along the ventral side are so closely intermingled with the dorsal ones, that no dividing line can be distinguished.

In *Archæocrinus desideratus*, which is a good typical form of the genus, there are twenty or more interradials beneath the horizon of the arms, and these are succeeded by a much larger number of minute pieces at the ventral side, all of which, from the basals up, decrease in size to the oral pole. There are no large plates to represent the proximal dome plates, and hence no orals if these were represented by the proximals as contended by Carpenter. The interradial and interaxillary spaces in the dome are depressed, thereby producing along the surface somewhat irregular ridges, which follow the direction of the subtegminal ambulacral tubes.

The depressed globular form and the wide interradial spaces of the calyx are characteristic features of *Archæocrinus*, which distinguish it readily from all other Silurian Rhodocrinidæ.

Some of our specimens of *Archæocrinus sculptus* have beneath the first interradial plate, resting upon the basals, two small additional plates. As these are present only in the larger specimens, and totally absent in the smaller ones, in some of them developed in a most rudimentary way, sometimes only in one or two of their rays, it is evident that they are the result of extravagant growth, and not true interradial plates. They seem to us equivalents of the small accessory pieces between basals and radials in *Acrocrinus*, in which they attain a much more profuse development, occupying the greater part of the calyx.

We note here the following additional species:

1884. **Archæocrinus desideratus** Walter R. Billings MS. (The description will appear in the Transactions of the Field Naturalist's Club of Ottawa.)

*1880. (?) **Archæocr. globularis** Nichols. and Ether., Silur. Fossils Girvan Distr., p. 329, Pl. 22, figs. 9-11.—Craighead limestone.

*1882. **Archæocrinus sculptus** (S. A. Miller), **Lyriocrinus sculptus,** Cincin. Journ. Nat. Hist., vol. v, p. 217, Pl. 3, figs. 6 a, b.—Trenton limest. Knoxville, Tenn.

Syn. **Lyriocrinus sculptilis** S. A. Miller. Name preoccupied.

RHAPHANOCRINUS nov. gen.

(*ῥάφανος*, a radish; *κρίνον*, a lily.)

Syn. *Glyptocrinus* Walcott (in part), not Hall, 1883, New Spec. of Foss. from Trenton gr. of N. York, p. 2. (Abstract from the 35th Rep. N. York State Museum Nat Hist., N. York.)

The species upon which the genus *Rhaphanocrinus* is proposed, was referred by Walcott, with some doubt, to *Glyptocrinus*. Like that genus, it has regularly arranged interradial plates, but these rest upon the truncate upper side of the basals, not upon the sloping sides of the first radials as in that genus; besides it possesses underbasals. The latter plates were not observed by Walcott; they are evidently small, and covered by the large column or hidden within the basal concavity. That underbasals were present, is clearly seen by the angular form of the first radials, and by the form, size and position of the basals.

Rhaphanocrinus is closely allied to *Archæocrinus*, from which it differs in having the arms constructed of a single series of quadrangular plates, and in having simple, in place of branching, arms. It also resembles *Dimerocrinus* in its general aspect, but is readily distinguished by the position of the interradial plates, and by having the arms constructed of a single series of plates. It differs from *Anthemocrinus*, with which it has probably the closest affinities, in the entirely distinct arm structure.

Generic Diagnosis.—Calyx short, truncate below; interradial spaces slightly depressed.

Underbasals small, not visible in a lateral view, and more or less hidden by the column. Basals large, hexagonal, the upper side truncate for the reception of the first interradials.

Primary radials 3×5, large; the first and third nearly alike in form. Secondary radials two or more, quadrangular; gradually decreasing in height and passing into arm plates.

Interradials numerous; those of the ventral side smaller. Interaxillary plates few. Summit plates, and form of anus unknown.

Arms stout, long, simple; composed of a single series of quadrangular plates, which give off alternately strong pinnules. Column large; cylindrical.

The type of the genus, and only known species is:

*1883. **Rhaphanocrinus subnodosus** (Walcott), **Glyptocrinus** (?) **subnodosus**, 35th Rep. N. York State Mus. Nat. Hist., Pl. 17, fig. 3.—Trenton limest. Trenton Fall, N. Y.

LYRIOCRINUS Hall.

(W. and Sp., Revision II, p. 203.)

Not *Lyriocrinus* S. A. Miller, 1882, Journ. Cincin. Soc. Nat. Hist., vol. v, p. 217.

(?) **SAGENOCRINUS** Angelin, Rev. II, p. 201.

RHIPIDOCRINUS Beyrich, Rev. II, p. 205.

THYLACOCRINUS Oehlert, Rev. II, p. 207.

1879. *Thylacocr. Vanniosti* Oehlert, Extr. du Bull. Soc. Géol. de France (Ser. 3), vii, Pl. i, fig. 1; also 1882, ibid. vol. x, p. 359, fig. 1.—Devonian. St. Germain, France.

ANTHEMOCRINUS W. and Sp. Rev. ii, p. 208.

RHODOCRINUS Miller, Rev. ii, p. 209.

1882. *Rhodocr. coxanus* Worthen, Bull. i, Illinois St. Mus. Nat. Hist., p. 80; also Geol. Rep. Illinois, vii, p. 305.—Keokuk limest. Keokuk, Iowa.

OLLACRINUS Cumberland, Rev. ii, p. 213.

Family III.—GLYPTASTERIDÆ W. and Sp.

PTYCHOCRINUS nov. gen.

(πτύξ a fold; κρίνον a lily).

Mr. S. A. Miller has arrayed a number of species under a proposed genus *Gaurocrinus*, which, like his *Glyptocrinus*, embraces a heterogeneous assemblage of forms. It contains species of *Reteocrinus*, *Glyptocrinus*, and a new form with good generic characters, in our opinion, for which we should be very glad to retain Miller's name, if he had not expressly taken as its type Hall's *Glyptocrinus O'Nealli*, which is a typical *Reteocrinus*. We are, therefore, obliged to adopt a new name, and propose *Ptychocrinus*, for the reception of his *Gaurocrinus splendens*, and *G. angularis*, together

with Hall's *Glyptocrinus parvus*, which, evidently, according to Hall's figure (but not Meek's), has the same characters.

We cannot agree with Miller that Wetherby's *Reteocrinus gracilis*, in which ill-formed interradials separate the radials down to the base, and in which the basals are squarely truncated above and form the base of the interradial spaces, is a synonym of *Glyptocrinus angularis*, in which the "interradial spaces have a hexagonal plate resting between the upper sloping side of the first radials."

The three species differ from all established genera of this family in having their arms constructed of single joints. It might, perhaps, be doubted whether this is a good generic character, as all Crinoids with double-jointed arms are single-jointed in their younger stages; but finding three species with the same kind of arms, and these comprising the only known Lower Silurian species of this family, we are evidently justified in making it a generic distinction.

Generic Diagnosis.—In general form closely resembling *Glyptocrinus.* Radials with a fold-like, strong, tubular ridge along their median line; interradial spaces depressed.

Underbasals five, well shown in a side view. Basals five, large; all of them hexagonal. Primary radials 3×5; the first ones heptagonal, but the upper sloping sides facing the azygous side longer, forming a deep notch for the reception of a very large anal plate. Secondary radials three or more, which have the appearance of arm-plates, and gradually pass into free joints. They have strong arm-like pinnules, given off from alternate sides.

Interradials consisting of one plate in the first row, two in the second, and three in the third row. The azygous side wider; the first plate extending far down between the first radials, sometimes touching the basals, and there are three in place of two plates in the second series. Structure of the ventral side unknown. Column small; cylindrical.

*1879. **Ptychocrinus angularis** (Miller and Dyer), **Glyptocr. angularis**, Journ. Cincin. Soc. Nat. Hist., p. 5, Pl. 1, fig. 10.—1883, **Gaurocr. angularis** S. A. Miller, Journ. Cincin. Soc. Nat. Hist., vol. vi, p. 229.—Hudson River gr. Cincinnati, Ohio.

*1872. **Pt. parvus** (Hall), **Glyptocr. parvus**, Desc. New Crin., etc., Pl. 1, fig. 17 (without description), 24th Rep. N. Y. State Cab. Nat. Hist., p. 207, Pl. v, fig. 17; (?) Meek, 1873, Geol. Rep. Ohio, Pal. i, p. 36, Pl. 2, figs. 4 a b; (?)

S. A. Miller, 1883, Journ. Cincin. Soc. Nat. Hist., vol. vi, p. 224.—Hudson gr. Cincinnati, Ohio.

Meek's description of this species, upon which the Cincinnati paleontologists have tried to identify it, is based upon specimens which did not show its characters, and therefore cannot be relied upon. Hall's figure exhibits a well-marked form, it shows plainly that it must have underbasals, and that a small anal plate extends down to the basals.

*1883. **Pt. splendens** (S. A. Miller), **Gaurocr. splendens**, Journ. Cincin. Soc. Nat. Hist., vol. vi, p. 230.—Trenton gr. Cape Girardeau, Mo.

GLYPTASTER Hall, Rev. ii, p. 193.

Additional species :—

1881. *Gl. Egani* S. A. Miller. Journ. Cincin. Soc. Nat. Hist., vol. iv (October), Pl. 6, figs. 4 a b.—Niagara gr. Chicago, Ill.

1882. *Gl. occidentalis* var. *crebescens* Hall. Eleventh Geol. Rep. Indiana, by Collett, p. 263.—Niagara gr. Waldron, Ind.

EUCRINUS Angelin, Rev. ii, p. 196.

DIMEROCRINUS Phillips, Rev. ii, p. 197.

Additional species :—

*1882. **D. waldronensis** (Miller and Dyer), **Cyathocrinus waldronensis**, Journ. Cincin. Soc. Nat. Hist., July (Abstr., p. 6), Pl. 4, fig. 9.—Niagara gr. (We have seen in the collection of Mr. Wm. Gurley, of Danville, a specimen which shows plainly the presence of dorsal interradials; and this feature, together with the double-jointed arm structure, proves, beyond doubt, that it is not a Cyathocrinoid).

LAMPTEROCRINUS Roemer, Rev. ii, p. 199.

Additional species :—

1879. (?) **L. parvus** Hall, Trans. Alb. Inst., vol. x (Abstr., p. 9).—Niagara gr. Waldron, Ind. (This may be a young specimen of **L. tennesseensis**. It apparently differs only in the much smaller size, and in having but four anal plates).

FAMILY IV.—MELOCRINIDÆ Roemer.

(Emend. W. and Sp.).

a. STELIDIOCRINITES.

(?) **BRIAROCRINUS** Angl., Rev. ii, p. 96.

This is one of the genera in which we cannot trace satisfactorily the family relations, being in some of the characters allied to the Ichthyocrinidæ.

STELIDIOCRINUS Angl., Rev. ii, p. 98.

Additional species :—

*1883. (?) **Stelidiocrinus argutus** (Walcott), **Glyptocrinus argutus**, 35th Rep. N. York State Cab. Nat. Hist. (Adv. Sheet, p. 1), Pl. 17, fig. 9.—Trenton limest. Trenton Falls, N. Y. This is certainly not a **Glyptocrinus**. To judge from the figure, it is closely allied to **Stelidiocrinus**, but may be the type of a new genus.

PATELLIOCRINUS Angl., Rev. ii, p. 100.

MACROSTYLOCRINUS Hall, Rev. ii, p. 102.

Additional species :—

1882. **Macrostylocr. fusibrachiatus** Ringeberg, Journ. Cincin. Soc. Nat. Hist., vol. v, p. 119, Pl. 5, fig. 4.—Niagara gr. Lockport, N. Y.

1880. **M. striatus**, var. **granulosus** Hall, 28th Rep. N. Y. State Cab., p. 129; also 11th Geol. Rep. Ind., p. 258.—Niagara gr. Waldron, Ind.

CENTROCRINUS W. and Sp., Rev. ii, p. 104.

b. MELOCRINITES.

GLYPTOCRINUS Hall, Rev. ii, p. 185.

1883. S. A. Miller. Journ. Cincin. Soc. Nat. Hist., vol. vi (December).
1883. W. and Sp. Amer. Journ. Sci. (April), p. 255.
1883. S. A. Miller. *Ibid.* (August), p. 105.
Not Etheridge and Nicholson, 1880, Silur. Foss. of Girvan Distr., p. 328.
Syn. *Pycnocrinus* S. A. Miller. Journ. Cincin. Soc. Nat. Hist., vol. iv.

Since the absence of underbasals is clearly proved, *Glyptocrinus* differs from *Mariacrinus* only in the number of basals, which is five in place of four. Miller has founded the genus *Pycnocrinus* upon a species which he had previously referred to *Glyptocrinus*. Through the liberality of Mr. Miller, for which we are under lasting obligations to him, we have been given the freest access to his beautiful type specimens, with liberty to use them for our descriptions. We are reluctantly compelled to say that in our opinion *Pycnocrinus* is simply a young *Glyptocrinus*. The genus was founded principally upon the absence of "secondary radials," and the arms were said "to arise free from the primary radials." This statement does not agree with our observations, as we find in two of the specimens a minute interaxillary piece, and at least one secondary radial. In the two others, which are even more immature, the third primary radials, in part, take the functions of

the secondary radials, as seen by the surface ridges, which bifurcate along the middle portions of the plates. The plates succeeding them are still in a free state, and appear as arm-plates, but actually form extensions of the calyx, being not as yet connected by interradials and interaxillaries, as in the more adult specimens. A diversity in the number of secondary radials cannot be considered of generic value, at least not in a form like *Glyptocrinus*, in which, as Miller himself has shown us (Journ. Cincin. Soc., vol. vi, Pl. 11, fig. 1), the rays remain in an immature condition, more or less, even in the adult. The specimens referred to *Pycnocrinus* are so embryonic in their condition, that it would be speculation for us to assert to what species they belong, and we have concluded to leave them as doubtful species under *Glyptocrinus*.

The species now referred by us to *Glyptocrinus* have round columns, with the exception of *Glyptocrinus Fornshelli*, which Miller thinks may prove to be a distinct generic form ; while those referred to *Reteocrinus*, with probably one exception, have pentagonal columns.

The species which were referred in Europe to *Glyptocrinus*, probably with the exception of *Glyptocrinus basalis* (?), belong to different genera. That species was figured without discription in Murchison's Siluria, p. 206, from a specimen with arms, and came from the Caradoc limestone. In this specimen, the plates of the calyx cannot be recognized, but the arms are those of *Glyptocrinus*. In the type specimen of McCoy, in which only the calyx is preserved, the interradials apparently touch the basals, which, if true, would exclude it from *Glyptocrinus*.

The specimens described by Nicholson and Etheridge, jun., under the name of *Glyptocr. globularis*, from the Craighead limestone and from Traive Glen. (Monogr. Silur. Foss. Girvan Distr. in Ayshire, 1880, pp. 328–30, Pl. 22, figs 9–11), probably belong to *Archæocrinus*. They evidently had underbasals, for the interradials rest upon the basals, and alternate with the first radial plates. Neither can the arms, fig. 12, on the same plate, which are composed of a double series of joints, be referred to *Glyptocrinus*.

We add the following species to our former list:

(?) 1854. **Glyptocrinus basalis** McCoy, Synops. Palaeoz. Foss., p. 57, plate I D, fig. 4, 1859, Murchison's Silur., p. 206.—Caradoc limest. Montgomeryshire, Great Britain.

1882. **G. miamiensis** S. A. Miller, Journ. Cincin. Soc. Nat. Hist., vol. 5, Pl. 1, fig. 1. Ibid., 1883, vol. vi, p. 224.—Hudson River gr. Waynesville, O.

1882. **G. sculptus** S. A. Miller, Journ., Cincin. Soc., vol. v, p. 13, Pl. 1, fig. 2; also Ibid., 1883, vol. vi, p. 224, Pl. 1, fig. 2.—Hudson River gr. Waynesville, O.

MARIACRINUS Hall, Rev. ii, p. 114.

Syn. *Compsocrinus* S. A. Miller, 1883, Journ. Cincin. Soc. Nat. Hist., vol. vi, p. 234.

Compsocrinus was described by Miller from a species which was said to possess a quadripartite base, supporting five radials and an anal plate; column quadrangular. Good specimens of "*Compsocrinus*" *Harrisi*, Miller's type, from the collection of Mr. Harris, who has the type specimens, show the number of basals to be four, as described by Miller; but the interradials at all sides rest upon the first radials, the posterior one not abutting against the basals as was asserted, and this makes *Compsocrinus* identical in structure with *Mariacrinus* as emended by us. If Miller's diagnosis had been correct, *Compsocrinus* would have been undoubtedly a good genus. Whether the column in other species of *Mariacrinus* is quadrangular, is not known.

*1881. **Mariacrinus Harrisi** (S. A. Miller), **Glyptocrinus Harrisi**, Journ. Cincin. Soc., vol. iv, Pl. 1, fig. 4.—**Compsocrinus Harrisi** Miller, Ibid., vol. vi, p. 234, Pl. 11, fig. 4.—Hudson River gr. Waynesville, O.

TECHNOCRINUS Hall, Rev. ii, p. 116.

MELOCRINUS Goldf., Rev. ii, p. 118.

1883. *M. Benedeni* (Dewalque MS.) Fraipont, Rech. sur les Crin. du Famenien de Belgique, Ann. de la Soc. géol. de Belg., Tome x, p. 60, Pl. 4, fig. 9.—Devon. superieur. Senzeille, Belgium.

1883. *M. Chapuisi* (Dewalque MS.) Fraipont, Ibid., p. 65, Pl. 5, figs. 5–7.—Devon. superieur. Senzeille, Belgium.

1882. *M. Clarkei* Williams, Proc. Acad. Nat. Sci. Phila., p. 31.—Genessee slate. Ontario Co., N. Y.

M. gerolsteinensis Steininger, 1853, Geogn. Beschreib. d. Eifel, p. 35, is not sufficiently defined for identification.

1883. *M. globosus* (Dewalque MS.) Fraipont, Rech. sur les Crin. du Famenien de Belg. Ann. Soc. géol. de Belg., Tome x, p. 61, Pl. 5, figs. 1–4.—Devon. superieur. Senzeille, Belgium.

1884. *M. inornatus* (Dewalque MS.) Fraipont, Ibid., Tome xi, p. 105, Pl. 1, fig. 1.—Devon. superieur. Frasne, Belgium.

1883. *M. Konincki* (Dewalque MS.) Fraipont, Ibid., p. 58, Pl. 4, figs. 6–8. Devon. superieur. Senzeille, Belgium.

1883. *M. mespiliformes* (Dewalque MS.) Fraipont, Ibid. p. 63, Pl. 5, figs. 8–10.—Devon. superieur. Senzeille, Belgium.
1882. *M. occidentalis* Oehlert, Bull. Soc. géol. de France (ser. 3), Tome x, p. 357, Pl. 8, fig 4.—Devon. inferieur. Near Sabré and La Flèche, France.
1883. *M. Oehlerti* W. and Sp. *Melocrinus Verneuili* Oehlert (not W. and Sp., 1881). Described Soc. géol. de France (Ser. 3), Tome x, p. 358, Pl. 8, fig. 5.—Devon. inferieur.—Sabré, France.
1884. *M. obscurus* (Dewalque MS.) Fraipont, Ibid., vol. xi, p. 107, Pl. 1, fig. 2.—Devon. superieur. Chaud fontaine, Belg.

SCYPHOCRINUS Zenker, Rev. ii, p. 123.

(?) **HADROCRINUS** Lyon, Rev. ii, p. 222.

DOLATOCRINUS Lyon, Rev. ii, p. 124.

1884. *D. triadactylus* Barris, Proceed. Davenport. Acad. Nat. Sci., vol. iv, Pl. 2, figs 5–7.—Hamilton gr. Alpena, Mich.
1871. *D. ornatus* Meek, Proc. Acad. Nat. Sci. Phila., p. 57.—Corniferous. Columbus, O.

STEREOCRINUS Barris, Rev. ii, p. 126.

FAMILY V.—ACTINOCRINIDÆ Roemer.

a. AGARICOCRINITES.

CARPOCRINUS Müller, Rev. ii, p. 105.

NOTE.—In Rev. ii, p. 107, in place of *Carpocrinus elongatulus* read *C. elegantulus.*

(?) **LEPTOCRINUS** Angl., Icon. Crin. Suec., p. 3.

This genus was placed by Angelin under Platycrinidæ, but, if we understand the figure correctly, it is not only an Actinocrinoid, but even synonymous with *Carpocrinus.*

Additional species :—

1879. **Leptocrinus raridigitatus** Angl., Iconogr. Crin. Suec., p. 3, Pl. 20, figs. 18, 19, and Pl. 28, figs. 4, 4 a.—Upper Silurian. Gothland, Sweden.

DESMIDOCRINUS Angl., Rev. ii, p. 108.

AGARICOCRINUS Troost, Rev. ii, p. 109.

Additional species :—

1881. **A. crassus** Wetherby, Journ. Cincin. Soc. Nat. Hist., vol. v, p. 178, Pl. 5, fig. 1 a b.—Keokuk gr. Kentucky.

1881. **A. elegans** Wetherby, Journ. Cincin. Soc. Nat. Hist., vol. v, p. 179, Pl. 5, fig. 4 a b.—Keokuk gr. Kentucky.

ALLOPROSALLOCRINUS Lyon and Cass., Rev. ii, p. 113.

b. PERIECHOCRINITES.

PERIECHOCRINUS Austin, Rev. ii, p. 127.

S. A. Miller's late additions to this genus were made from natural casts, and there is the usual uncertainty as to their identification. We must consider them as doubtful species, until the external surface is known from casts or otherwise. Miller considers *Megistocrinus infelix* Winch. and Marcy, *Saccocrinus infelix* Miller, specifically distinct from *Saccocrinus Christyi* Hall, which Hall had doubted. He gives two more figures of the species, Journ. Cincin. Soc. Nat. Hist., vol. iv, Pl. 6, figs. 2 *a b.*

Additional species :—

*1881. **Periechocr. Egani?** (S. A. Miller). **Saccocrinus Egani,** Journ. Cincin. Soc. Nat. Hist., Pl. 4, figs. 4, 4 a.—Niagara gr. Chicago, Ill.

*1865. **Periechocr. necis?** (Winchel and Marcy). **Megistocrinus necis,** Memoirs Bost. Soc. Nat. Hist., i, p. 111, Pl. 2, fig. 15. S. A. Miller, **Saccocrinus necis,** Journ. Cincin. Soc. Nat. Hist., 1881, Pl. 4, figs. 3, 3 a.—Niagara gr. Chicago, Ill.

*1882. **Periechocr. pyriformis?** (S. A. Miller). **Saccocrinus pyriformis,** Journ. Cincin. Soc. Nat. Hist. (July), Pl. 3, figs. 3, 3 a.—Niagara gr. Chicago, Ill.

*1882. **Periechocr. urniformis?** (S. A. Miller). **Saccocrinus urniformis,** Journ. Cincin. Soc. Nat. Hist. (July), Pl. 4, figs. 2, 2 a.—Niagara gr. Chicago, Ill.

ABACOCRINUS Angelin, Rev. ii, p. 133.

CORYMBOCRINUS Angelin.

1878. Angelin, Iconogr. Crin. Suec., p. 18.
1879. Zittel, Handb. d. Palæontologie i, p. 373.
Syn. *Eucalyptocrinus* McCoy, 1855 (not Goldfuss).
Syn. *Clonocrinus* Quenstedt, 1876 (not Oehlert, 1879).

The genus *Corymbocrinus* was in Pt. ii erroneously referred by us to the Calyptocrinidæ. It resembles *Eucalyptocrinus* so remarkably in the construction of the calyx plates, its deep basal concavity, and the perfect symmetry that prevails throughout the interradii, that we took it to be a connecting link between Actionocrinidæ and Calyptocrinidæ, but nearer the latter through *Callicrinus*, which we thought to be intermediate between *Corymbocrinus* and *Eucalyptocrinus*. To this view even the branching arms formed no serious objection, as Angelin has figured in the

Iconographia, Pl. 9, fig. 13, a malformed specimen of *Eucalyptocrinus*, in which some of the arms divide half-way up to the top, and in a similar manner, as in *Corymbocrinus*. Prof. Lindström, of Stockholm, however, informs us that the plates along the ventral side differ essentially in the two forms, and that the genus, in his opinion, could not be arranged with the Calyptocrinidæ. The total absence of special anal plates, unites it with the Melocrinidæ, and in this we agree with Zittel, but not with Angelin, who separated *Corymbocrinus* and *Abacocrinus* from *Melocrinus*, and placed them in separate families. The two genera have a similar arm-structure, but differ essentially in the construction of the calyx, the one having a strictly pentamerous, the other a decidedly bilateral symmetry. More close are the affinities with *Polypeltes*, provided we understand that genus correctly. We are somewhat in doubt whether Quenstedt's name *Clonocrinus*, should not be adopted in place of *Corymbocrinus*, as it probably has priority, but Quenstedt gives no generic description, only mentioning the name in connection with a certain species.

Generic Diagnosis.—Calyx basin, or low cup-shaped; basal portions broadly and deeply excavated; plates of very uniform size, rather heavy, somewhat convex, rarely ornamented; symmetry regularly equilateral, except in the basals.

Basals four, unequal, forming a hollow cone, which is filled by the upper portions of the column.

Primary radials 3×5, all wider than high. The first plate larger than the rest, its lower (here inner) side forming a part of the basal concavity, its opposite side at right angles with the column, only a small portion curved upward. The second radials quadrangular or nearly so, much wider than high, frequently with convex lower edges, narrower than the first radials. The third radials are pentagonal. Secondary radials $2 \times 2 \times 5$, comparatively large. Their upper series support two rows of transversely linear tertiary radials, arranged alternately like a double series of arm plates, but connected by interradial and interaxillary pieces, and hence forming parts of the body.

Arms long, bifurcating, gradually tapering to the distal ends; from their base up composed of a double series of very short but wide interlocking pieces. Pinnules long.

Interradials arranged longitudinally in rows of a single plate each. The first plate the largest in the calyx; ninesided; it ex-

tends from the upper sloping sides of the first primary radials to the first plate of the secondary radials. The second plate is much smaller, though yet comparatively large; it is hexagonal, and placed upon the first interradial and between the two secondary radials. There are two more interradial pieces above, which, like the two former, are longitudinally arranged. This arrangement is uniform in all five areas.

Interaxillary plates, one or two; the upper one cuneate, and inserted like the upper interradials between the tertiary radials. Construction of the plates of the ventral side unknown. The column is large, round, composed of low segments; articular faces provided with radiating striæ, except upon a small zone next to the periphery; central canal pentalobate.

Geological position, etc.—*Corymbocrinus* is only known from the Upper Silurian of England and Gothland.

Angelin refers to it the following species:

1840. **Corymbocr. corolliferus** Hisinger (**Cyathocr.** (?) **corolliferus**). Lethæa. Suec. Suppl. sec., p. 6, Pl. 39, fig. 3, a–c. Angelin, 1878.—**Corymbocr. corolliferus**, Iconogr. Crin. Suec., p. 18, Pl. 23, fig. 19.—Upper Silurian. Gothland, Sweden.

1878. **Corymbocr. grandis** Angelin. Iconogr. Crin. Suec., p. 18, Pl. 9, figs. 2, 3.—Upper Silurian. Gothland, Sweden.

1878. **Corymbocr. grandistellatus** Angelin. Iconogr. Crin. Suec., p. 18, Pl. 9, fig. 4, and Pl. 23, figs. 18–21.—Upper Silurian. Gothland, Sweden.

1878. **Corymbocr. laevis** Angelin. Iconogr. Crin. Suec., p. 18, Pl. 23, fig. 20.—Upper Silurian. Gothland, Sweden.

1878. **Corymbocr. Panderi** Angelin. Iconogr. Crin. Suec., p. 18, Pl. 9, fig. 5, and Pl. 23, figs. 17, 17 a, b.—Upper Silurian. Gothland, Sweden.

1855. **Corymbocr. polydactylus** McCoy (**Eucalyptocr polydactylus**). Apud. Sedgewick, Synops. Pal. Foss., p. 58, Pl. 1 D, fig. 2; also Salter, 1873; Catal., p. 120; Angelin, 1878.—**Corymbocr. polydactylus**, Iconogr. Crin. Suec., p. 18, Pl. 9, figs. 1, 6–12, and Pl. 21, fig. 17.—Upper Silurian. Gothland, Sweden.

NOTE.—It is possible that *Mariacrinus macropetalus* Hall, Paleont., N. York, vol. iii, p. 111, Pl. 3 A, fig. 1, is a *Corymbocrinus*, but it may be a *Callicrinus* in place of *Mariacrinus*, as which it was described.

(?) POLYPELTES Angelin.

1878. Angelin, Iconogr. Crin. Suec., p. 27.
1879. Zittel, Handb. d. Paleont. i, p. 373.

The genus *Polypeltes* was described as being composed of "8 or more basals, 16 parabasals, 10 (?) $\times$ 1 radials (all axillary), numerous interradial and interaxillary pieces, and as having

10×12 primary arms." This formula was considered by Angelin and Zittel so distinct from that of any other known form, that both placed the genus in an independent family. We should follow their example, if we were satisfied as to the correctness of that description.

From the fact that Angelin gave the number of most of the above plates with doubt—he stated positively only the number of "parabasalia"—we infer that his specimens in the basal regions were not in a condition for critical examination. It is, moreover, apparent that an arrangement of plates, such as he described, is theoretically, as well as practically, impossible.

From the description it is difficult to ascertain which of the plates were intended as "basals" and which as "parabasals." In fig. 2, Pl. 9, of the Iconographia, there are represented close to the column two rings of plates; an upper or outer one, which is composed of 25 or 26 pieces, and close to the column an inner one, which, if any reliance can be placed in the figure (?), contains very nearly the same number, for the plates are represented as alternating with those of the upper ring. The former should contain the "parabasals," the latter the basals; but unfortunately the plates of both rings differ in number most conspicuously from the number attributed to "basals" and "parabasals" in the description.

Of all the plates to which the description alludes, the "ten (?) bifurcating radials" are most readily recognized, and we believe there are actually ten of these plates in the specimen. In the figure they occupy a position within the second ring, but along with other plates which are interposed between them. At the one side there is a small single piece, which we take to be an interaxillary plate; at the other are found two larger plates, evidently interradials, with possibly an additional anal piece at the posterior side. It is very probable that these 15 or 16 plates, which in groups of one, two, and three (?) are inserted laterally between the axillary radials, were taken in the description for "parabasalia," as otherwise those plates would be undescribed. If this is the case, the term has been incorrectly applied, as the name "parabasalia" has been given only to the ring of plates which lies beneath the radials, and between these and the underbasals. All plates which are laterally inserted between the radials, as in this case, are called interradials. It would be, however, equally incon-

sistent in principle to search for "parabasalia" among the plates of the first ring, for basals and "parabasals" are not placed beside each other, but the latter rest upon the ring of the former. We doubt if *Polypeltes* possessed any such plates as "parabasalia," at least not among the plates of these two rings. It is probable that the plates of the inner ring, like those of the outer, were partly radials and partly interradials, while the basals were hidden from view by the column. In support of this view it is well to compare the plates here exposed with those represented in allied genera.

According to description, the ten bifurcating radials are succeeded by two rows of from four to five plates, consisting of higher orders of radials; the upper series bifurcating, giving off another order of radials, and these the primary arms, which branch after becoming free. Comparing the different portions of the rays with the same parts in *Abacocrinus* and *Corymbocrinus*, we find the form of the radials, their proportionate size, and even the construction of the arms and their mode of branching, almost identical with those two forms, provided we compare the ten lower radials in *Polypeltes* with the ten rows of secondary radials in *Abacocrinus* and *Corymbocrinus*. The main difference is that the latter genus has but one bifurcation in the calyx above these plates, while the former has two, and consequently twice the number of primary arms, a difference only of specific value. From the fact that *Polypeltes* has an extra bifurcation, and twice as many primary arms as the other two genera, it might be asserted that it has exceptionally ten primary rays instead of five, and ten interradial spaces, but that is not the case. It has been stated that the ten radials are laterally disconnected, and separated on the one side by a single plate, and on the other by two larger pieces. The two larger ones are followed by numerous other plates, which, arranged in two rows, extend to the lower portions of the arms, and enclose these within the calyx, while the smaller plate at the other side stands perfectly isolated, surrounded on all sides by radials. That the former represent the plates of five interradial series, and the single piece an axillary plate, has been already stated, and this proves very clearly that *Polypeltes*, like other Crinoids, has but five main rays, that the ten axillary pieces in Angelin's figure represent $1 \times 5 \times 2$ secondary radials, and that the specimen must have somewhere primary radials.

Beneath the interaxillary plate, the figure indicates the presence of two plates, separated laterally, which, combined, have the form and position of a bifurcating plate. That there is a mistake in the figure with regard to these plates, seems to us beyond question. There is evidently but one plate in the specimen, and this represents a primary radial, while the two plates at each side of it, as in the succeeding ring, are interradials. The figures do not extend beyond this ring, all lower plates being evidently hidden from view by the large column, and hence the exact number of primary radials and basals is not known, but this was undoubtedly similar to that of allied genera, and not so abnormal as given by Angelin.

If it has three primary radials and four basals, which seems to us most probable, and at the same time a distinct anal interradius, we should not hesitate to place *Polypeltes* as a synonym under *Abacocrinus*, while under the same conditions, but with only three basals, it agrees with *Megistocrinus.* However, should it be proved that the posterior interradius has no additional plates, but is constructed like that of the four other sides, *Polypeltes* should be placed under *Corymbocrinus.* Only a variation in the number of primary radials, if our interpretation is correct, will warrant a generic separation, but in this case the name should be changed, as it becomes meaningless.

We suggest that in *Polypeltes* (?) the basals and the greater part of the primary radials form a deep concavity, which, to a large extent, is filled by the column, as in the case of *Corymbocrinus*, *Megistocrinus* and *Eucalyptocrinus.* We found a very similar case in *Megistocrinus concavus* Wachsmuth, from Alpena, Michigan, in which the basals and first radials form the lateral walls of a deep concavity, and are entirely hidden from view. The second radials are partly exposed, and form, with adjoining pieces, a ring of twelve very even, strongly nodose plates, which consist of five radials, four regular interradials, and three anal plates. Nobody would suspect one of these specimens to be a *Megistocrinus*, unless he obtained access to the deep funnel which contains the missing plates.

We deem it unnecessary to give a special diagnosis of *Polypeltes*, as we think it will eventually be placed under *Abacocrinus* or *Corymbocrinus.* It has the same long, branching arms, composed of two series of narrow interlocking pieces, and, as in that

genus, the lower portions of the arms are connected laterally for some distance by one or two rows of interbrachial pieces.

Angelin described under *Polypeltes* a single species :—

1878. (?) **Polypeltes granulatus** Angelin. Iconogr. Crin. Suec., p. 27, Pl. 24, figs. 2, 3.—Upper Silurian. Gothland, Sweden.

MEGISTOCRINUS Owen and Shum., Rev. ii, p. 135.

We compared *Megistocr. ontario* Hall, and *M. depressus* Hall, with good specimens in our own cabinet and in the Canada Survey Museum, and find the former to be a young example of *M. abnormis* Lyon, the latter of *M. rugosus* Lyon and Cass.

Additional species :—

1879. **M. pileatus** S. A. Miller. Journ. Cincin. Soc. Nat. Hist. (December), Pl. 10, figs. 1 a b.—Corniferous limest. Columbus, O.—This must be closely compared with **M. rugosus** Lyon and Cass., with which it may be identical.

1885. **M. concavus** Wachsmuth. Proceed. Davenport Acad. Sci., vol. iv, p. 96, Pl. 1, figs. 5–7.—Alpena, Mich.

*1836. **M. globosus** (Phill.) **Actinocr. globosus**, Geol. Yorkshire, p. 206, Pl. 4, figs. 26–29, also McCoy, 1844, Synops. Carb. Foss. Ireland, p. 182; W. and Spr. **Rhodocr. globosus**, Rev. ii, p. 212.—Mount. limest. England.

1885. **M. nodosus**, var. **multidecoratus** Barris. Proceed. Davenport Acad. Nat. Sci., vol. iv, p. 100.—Hamilton gr. Alpena, Mich.

c. ACTINOCRINITES.

ACTINOCRINUS Miller, Rev. ii, p. 138.

Phillipsocrinus caryocrinoides McCoy, Synops. Carb. Foss. Ireland, p. 183, Pl. 26, fig. 5, is evidently an abnormal specimen of *Actinocrinus pusillus* or some other closely allied species.

Actinocr. dalyanus S. A. Miller, 1881, is a synonym of *Actinocr. proboscidialis* Hall, and it is from the Lower Burlington limestone, not from the Keokuk limestone, as supposed by Miller.

A. tholus Hall. It is possible that the form which Hall described under this name, and which we took to be a synonym of *A. glans*, is more than a mere variety. We found lately in one and the same locality numerous specimens agreeing well with Hall's description, every one having convex or even slightly nodose plates; while those of *A. glans* are generally smooth or merely convex, and the form of the body is somewhat more elongate.

Additional species :—

1860. **A. spinotentaculus** Hall, Suppl. Geol. Rep. Iowa, I, p. 86.—Lower Burlington limest.—Burlington, Iowa.

TELEIOCRINUS W. & Sp., Rev. ii, p. 146.

In the second part of the Catalogue of Amer. Pal. Foss., p. 268, Miller calls *Teleiocrinus* "a subgenus of doubtful utility." The fact is we proposed it as a full genus of the Actinocrinites and not a subgenus of *Strotocrinus.* We stated expressly, *Teleiocrinus* holds the same relation to *Actinocrinus* as *Strotocrinus* to *Physetocrinus*, which, curiously enough, are both accepted by Miller. Probably all these genera are descendants of *Actinocrinus*, and it is difficult to see how Miller can reject *Teleiocrinus* when he accepts *Strotocrinus.*

STEGANOCRINUS M. & W.., Rev. ii, p. 149.

AMPHORACRINUS Austin, Rev. ii, p. 151.

PHYSETOCRINUS M. &. W., Rev. ii, p. 155.

Additional species :—

*1881. **P. Copei** (S. A. Miller) **Actinocrinus Copei,** Jour. Cincin. Soc. Nat. Hist. (Decbr.), Pl. 7, figs. 2, 2 *a.*—This species, like all others which Miller described from New Mexico, came from the Lower Burlington limestone, and not from the Keokuk group.—Lake Valley, New Mexico.

STROTOCRINUS M. & W., Rev. ii, p. 158.

GENNÆOCRINUS W. & Sp., Rev. ii, p. 160.

d. BATOCRINITES.

BATOCRINUS Casseday, Rev. ii, p. 162.

Additional species :—

*1859. **B. grandis** (Lyon), **Actinocrinus grandis,** Amer. Journ. Sci., vol xxviii (September), p. 240.—Keokuk limest. Kentucky and Tennessee.—In the original description of this species, by mistake of the printer, the specific name was omitted. Lyon evidently intended to name the species **Act. grandis,** as that name is mentioned at the end of the description in discussing the geological position. We adopt this specific name, but place the species under **Batocrinus.** It has two arms extended from each arm base, a character only found among the Batocrinites.

ERETMOCRINUS Lyon & Cass., Rev. ii, p. 170.

Additional species :—

E. varsoviensis Worthen, 1882, Bull. i, Illinois State Mus. Nat. Hist., p. 30, and Geol. Rep. Ills., vol. vii, p. 306, Pl. 28, fig. 14. This species is synonymous with **E. originarius** W. & Sp.

DORYCRINUS Roemer, Rev. ii, p. 176.

Additional species :—

D. lineatus S. A. Miller, 1881, Journ. Cincin. Soc. Nat. Hist. (December), Pl. 7, figs. 3, 3 a, from New Mexico, is specifically identical with **D. unicornis** (O. & Shum.).

Family VI.—PLATYCRINIDÆ Roemer.

(Emend. W. & Sp.).

CULICOCRINUS Joh. Müller, Rev. ii, p. 61.

This genus is known only from casts, and reasonable doubts may be entertained as to the correctness of Müller's figures. That the whole ventral side had been covered by only five plates, as described by Müller, seemed to us not very probable, and we suggested in our description that perhaps it had been composed of eight pieces: a central plate, 6 proximals and an anal piece, of which the sutures had been obliterated. Of late, however, we are inclined to abandon this view, as the plates in question are too large to be proximals, neither can they be orals, for the larger plate is pierced by the anal opening. It seems to us *Culicocrinus* represents morphologically a still lower form than even *Coccocrinus*, that its ambulacra were subtegminal, and probably also the oral piece, unless this is represented by the tubercle in the larger plate.

COCCOCRINUS Joh. Müller. Rev. ii, p. 58.

(Revised).

In our generic description it was incorrectly stated that *Coccocrinus* had but a simple interradial to each side. This was partly due to a misunderstanding of the plates. The first range consists of three pieces, as clearly shown in *Coccocrinus bacca* Rœmer (Silur. Fauna West Tenn., Pl. 4, fig. 5 c). The middle plate, the one we described, rests within the notch of two first radials, the other two against the upper face of one of them, and against the second and third radials. A fourth plate, which we previously described as an oral plate, but which we regard now a secondary interradial, abuts against the upper faces of the three former. The plates of adjoining interradii do not touch laterally, but are separated by a very regular linear cleft, which extends all the way from the central gap to the arm furrows. There are nowhere

traces of ambulacra, which were probably hidden within the clefts, and partly covered by the interradials, instead of being placed, as we had supposed, on a level with them. A similar position was probably occupied by the central plate, which, in our opinion, formed the bottom part of the central space.

We have but little doubt that the conditions of *Coccocrinus rosaceus* were essentially the same as those of *C. bacca;* in the former, however, the outer interradials were not preserved, having been probably extended out to the free rays, as, more or less, in the case of all discoid species of *Platycrinus*. That they were present is indicated by the irregular width of the lateral clefts, which, as seen in the specimens, suddenly widen on approaching the arm bases, while they should rather grow narrower if representing the clefts between the orals in *Holopus*, as which they were regarded by Carpenter.

CORDYLOCRINUS Angelin, Rev. ii, p. 60.

MARSUPIOCRINUS Phillips, Rev. ii, p. 62.

Additional species :—

*1875. **M. præmaturus** (Hall), **Platycrinus præmaturus**, Geol. Rep. Ohio, Palæont. ii, p. 124, Pl. 6, figs. 3–6.—Niagara gr. Green Co., O.

PLATYCRINUS Miller, Rev. ii, p. 65.

Pl. discoideus Hall, 1858, not Owen and Shumard, 1850. = *Eucladocrinus pleuroviminus* White.

Additional species not noted before :—

1882. **P. monrœnsis** Worthen, Bull. i, Ill. State Mus. Nat. Hist., p. 30; also Geol. Rep. Ills. vii, p. 306, Pl. 30, fig. 9.—St. Louis limest. Monroe Co., Ill.—We have but little doubt that Prof. Worthen described here a young specimen of **P. bonœnsis** White.

1838. **Pl. coronatus** Goldfuss, Nova Acta, Leop. xix, i, p. 344, Pl. 31, fig. 8.—Carboniferous. Bristol, Engl.

Pl. bloomfieldensis S. A. Miller, syn. of **Platycrinus planus** O. and Shum.

Pl. poculum S. A. Miller. Too imperfect for identification.

Pl. vesiculus McCoy, Rev. ii, p. 76, read **Pl. vesiculosus.**

Pl. præmaturus Hall & Whitf. = **Marsupiocrinus præmaturus.**

EUCLADOCRINUS Meek, Rev. ii, p. 76.

COTYLEDONOCRINUS Cass and Lyon, Rev. ii, p. 77.

FAMILY VII.—HEXACRINIDÆ W. and Sp.

HEXACRINUS Austin, Rev. ii, p. 78.

Additional species :—

1884. **H. minor** (Dewalque MS.), Fraipont, Extrait des Ann. de la Soc. géol. de Belg., Tome xi, p. 110, Pl. 1, figs. 4 a and 4 b.—Devon. superieur. Senzeille, Belgium.

1884. **H. verucosus** (Dewalque MS.), Fraipont, Ibid., p. 108, Pl. 1, fig. 3.—Devon. superieur. Senzeille, Belgium.

1882. **H. Wachsmuthi** Oehlert, Bull. géol. de France (Ser. 3), Tome x. p. 355, Pl. 8, fig. 3.—Devon. inferieur. Sabré and La Fleche, France.

ARTHROACANTHA Williams.

1883. Williams, Proc. Am. Phil. Soc. (April), p. 84.
Syn. *Hystricrinus* Hinde, 1885, Ann. and Mag. Nat. Hist. (March), p. 158.

Prof. Williams proposed the name *Arthroacantha* in 1883, for a Crinoid of the *Hexacrinus* type with movable spines, of which he described and figured one species, *A. Ithacensis*, from the Chemung of New York. He also defined the characters of another species, from the Hamilton group, which had been named by Hall as *Platycrinus punctobrachiatus*, but not defined by him, except through the medium of a photograph privately distributed. To the latter species Williams gave the name *Arthroacantha punctobrachiata.*

In 1885, Dr. Hinde (Ann. and Mag. Nat. Hist., p. 158), proposed the name *Hystricrinus* for the genus defined by Williams, and described and figured a species, *H. Carpenteri*, from specimens derived from the Hamilton group of Ontario, Canada. He states that eminent authorities decided Williams' name to be invalid, by reason of its similarity to *Arthracanthus*, previously employed by Schmarda for a genus of Rotatoria. Examination of the question in the light of the Rules of the British Association, adopted in 1865, has led us to the conclusion that *Arthroacantha*, however injudiciously chosen to designate a genus of Crinoid, will have to stand. The tenth Rule (Am. Jour. Sci., July, 1869, p. 101) says: "A name should be changed which has before been proposed for some other genus in zoölogy or botany." It is evident from this that a proposed name may be ignored on account of identity with a prior name, but not by reason of mere similarity or resemblance

in form, however close. It is the word itself which determines its standing, and not its signification or derivation. The question is one of authority, and not of propriety or expediency, and it will be seen that the committee who reported the above-mentioned rule to the British Associaton, took the same view as to its effect that we do (Am. Journ., July, 1869, p. 107). *Arthroacantha* is a different word from *Arthracanthus*, although of the same etymology, and of similar construction, and there are other names of recognized standing in natural history, which bear a closer resemblance to prior names than this.

Another bibliographic question arises as to the species of this genus. Hall made a good figure of the type, which he called *Pl. punctobrachiatus*, but his plates were not published. Williams, however, when establishing the genus gave a brief but very clear definition of the characters of Hall's type specimen (Proc. Am. Phil. Soc., 1883, p. 83), and proposed for it the name *Arthroacantha punctobrachiata*. On p. 86 he again defined its principal characters by comparison with *A. ithacensis*. The "definition" necessary to impart authority to a published zoölogical term implies a "distinct exposition of essential characters." (See Committee's Report on Rule 12, Am. Journ., 1869, p. 102.) This was given by Williams far better than has been done in a great many specific descriptions of well known Crinoids. It is our opinion, therefore, that *A. punctobrachiata* is a good species, and that it must be credited to Williams. Whether Hinde's species is identical with *A. punctobrachiata* we cannot undertake to determine without more direct comparison of specimens. We have examined specimens from the Hamilton group of Ontario, Canada, which undoubtedly belong to *A. punctobrachiata*, and it is not improbable that *A. Carpenteri* may prove to be the same thing.

Arthroacantha is closely allied to *Hexacrinus*, from which it differs in having three primary radials instead of two, and movable spines along the surface of the plates. That the spines, which are frequently found in close proximity to the plates, are not mere broken parts of the plates, but constitute independent structures, is clearly seen from Prof. Williams' specimens, which he was good enough to send us for examination. The nature of the spines was disclosed to us more satisfactorily in specimens of *A. punctobrachiata* from the Hamilton of Canada, in which not only the calyx, but also portions of the arms were preserved, and in

which numerous detached spines lie upon the surface of the plates close to the tubercles from which they had been detached. That these spines, to some extent, were movable, is more than probable. They were evidently connected with the plates by elastic ligament, so as to yield when accidentally brought in contact with other objects, like the joints in a column, but we doubt if beyond this they represent, either functionally or structurally, the spines of the Echini.

These views differ somewhat from those held by Williams, who thinks it "not improbable that the original plates of *Lepidocentrus eifelianus*, described and figured by Johannes Müller, which were detached plates, associated with spines similar in nature to those just described and borne upon similar tubercles, were plates from the vault of a true Crinoid like *Arthroacantha*." And he remarks further, "we have here a possible clue to a relationship between true Crinoids and Perischœchinidæ.

There is in our opinion not the slightest doubt but that Müller's figures represent Echinoid plates, and that the spines which were found associated with them had the same functions as those of the true Urchins of later epochs; but we think that the spines of *Arthroacantha* form component parts of the plates taken separately, and as such we regard them as representing in a modified way the ordinary undivided spiniferous plates of other Crinoids. For this reason we cannot regard the movable spines of *Arthroacantha* of much more than of specific importance, but as the species also possess an additional primary radial, it may be well to separate them generically from species of *Hexacrinus* which do not have them. We allude to this more particularly, as Williams and also Hinde, was inclined to regard *Arthroacantha* as the type of a distinct family, a distinction, which, in our opinion, gives to the movability of the spines a degree of importance which it does from a morphological standpoint not deserve.

We also doubt if (?) *Arthroacantha Carpenteri* had whorls of cirrhi throughout the column, as supposed by Hinde. The columnar fragments which he figured on Pl. 4—if they belong to this species at all—evidently formed the lower portions of the stem, as shown by the size and the irregular arrangement of their branches, and as such are regarded by us merely as radicular cirrhi.

Generic Diagnosis.—In form and arrangement of plates closely

allied to *Hexacrinus*. All plates of the dorsal cup, the arm plates, and all interradial and summit plates, covered with numerous, irregularly arranged tubercles, provided centrally with a small pit for the reception of a long acicular spine.

Basals three, large, pentagonal. Primary radials 3×5; the lower one very large; the two upper ones small.

The anal plate has nearly form and size of the first radials, and occupies a similar position. The interradials are numerous and either cover the ambulacra completely, or open out to expose the covering plates. All plates of the calyx, dorsally and ventrally, except the basals, are provided with one or more movable spines, also the oral plate and proximals, but not the covering pieces, which, however, as stated, are not always exposed. Anus subcentral.

Arms two from each ray, simple or branching, and giving off slender pinnules from each joint. The proximal arm plates are composed of single cuneiform pieces, but these gradually interlock and turn into two series of alternate plates. Column round.

Geological position, etc.—*Arthroacantha* has been found in the upper part of the Devonian, and of America only.

1883. **Arthroacantha ithacensis** Williams, Type of the genus. Amer. Philos. Soc., April, p. 83, with figures.—Hamilton gr. Near Ithaca, N. Y.

1882. **A. punctobrachiata** Williams, Trans. Amer. Phil. Soc. (April), pp. 83 and 86 (figured by Hall as **Platycrinus punctobrachiatus**).—Hamilton gr. Ontario, Can.

*1885. **A. Carpenteri** (?) Hinde (**Hystricrinus Carpenteri**), Ann. and Mag. Nat. Hist. (March), p. 162, Pl. 4.—Hamilton gr. Ancona, Ontario, Can. (Probably a *Syn.* of **Arthroacantha punctobrachiata** Williams.

DICHOCRINUS Münster, Rev. ii, p. 81.

Additional species:—

1860. **D. lachrymosus** Hall, Suppl. Geol. Rep. Iowa by Hall, p. 84.—Upper Burlington limest. Burlington, Iowa.—This species was erroneously referred by us to **Platycrinus**, and was said to be synonymous with **Pl. subspinulosus**, with which it agrees in the ornamentation of the plates. Fine specimens which we obtained lately, have convinced us that it is a **Dichocrinus**, and was correctly separated by Hall. It has a comparatively large number of interradial plates, a very conspicuous oral, and six large proximal plates. The anal aperture is lateral, somewhat protruding, placed at the upper edge of one of the first interradials, which is somewhat excavated. The radial dome plates are composed of small alternate pieces which we followed up to the second bifurcation of the ray. Arms given off from the third secondary radials, whence they branch once or twice again, always from the third plate.

D. coxanus Worthen, 1882, Bull. i, Illinois State Mus., p. 35, and Geol. Rep. Ill., vol. vii, p. 313, Pl. 27, fig. 7, we take to be a mere synonym of **Dichocrinus ficus.**

1882. **D. hamiltonensis** Worthen, Bull. i, Ill. State Mus. Nat. Hist., p. 35; also Geol. Rep. Ill., vol. vii, p. 313, Pl. 27, fig. 10.—Keokuk limest. Hamilton, Ill.

TALAROCRINUS W. & Sp., Rev. ii, p. 85.

Additional species :—

1882. **T. ovatus** Worthen, Bull. i, Illinois State Mus. Nat. Hist., p. 36; also Geol. Rep. Ill., vii, p. 314, Pl. 19, fig. 11.—Kaskaskia, gr. Monroe Co., Ill.

PTEROTOCRINUS Lyon & Cass., Rev. ii, p. 87.

Family VIII.—ACROCRINIDÆ W. and Sp.

The Acrocrinidæ, so far as known, are represented by a single genus, and of this only three species have been described, two from the Chester (Kaskaskia) limestone, and one from the coal measures of America.

No attempt has ever been made to assign the genus *Acrocrinus* to its proper systematic position. Zittel and De Loriol in their classifications omit it entirely, and the descriptions by Yandell and Hall, which were from imperfect specimens, are indistinct and partly incorrect. Thanks to the kindness of Prof. Worthen, we have been able to examine a very perfect specimen of an undescribed species, which one of us described for volume vii of the Illinois Geological Report, and of which preliminary descriptions were published in Bulletin I, of the Illinois State Museum of Nat. Hist., p. 41. The specimen shows plainly that the base is bipartite, as Hall suspected, and not undivided, as stated by Yandell. Fortunately the other plates of the calyx were also in place, and in a condition to be critically examined.

Acrocrinus departs from most Palæocrinoidea in two important particulars, and upon these, mainly, the present family is founded. First : The plates of the calyx, which in all other species with large numbers of plates decrease in size from the basals to the arm bases, in *Acrocrinus* exhibit a decided increase in the same direction. Second : The radials are not connected with the basals, but separated from them by several rings of plates, which in position are partly radial, partly interradial, and which apparently are not represented in other genera of the Palæocrinoidea. This peculiar structure renders it exceedingly difficult in this

form to identify even those elements which are so readily recognized in other genera.

In *Acrocrinus Wortheni* Wachsmuth, the comparatively large basals are succeeded by a ring of twelve triangular plates, so minute, however, that it requires a magnifier to discover them. Another series of twelve larger plates constitutes the second ring. These plates are joined by their lateral edges, their lower angles resting between the preceding plates. Five of them have a radial direction, seven are placed interradially, one oppôsite each of the four regular interradial sides, three facing the anal side. Ten of the plates are hexagonal; only the middle one on the azygous side, and the plate which is directed to the anterior ray, are heptagonal. The two latter plates have truncate upper sides, which support, respectively, a vertical row of four very similar hexagonal pieces; one of them is interradial, and succeeded by anal plates, the other strictly radial.

The third ring consists of fourteen plates, larger than those of the preceding one. They are not so regularly arranged, and more variable in their size and form. Twelve of them alternate with the plates of the second ring, while the other two rest upon the truncate upper side of the heptagonal pieces just described. By this arrangement (see diagram, Pl. 9, fig. 1), the plate toward the anterior ray is the only plate in this ring which has a radial position, all others being located interradially, two to each of the four regular interradial sides, four to the azygous side.

The plates of the fourth ring differ considerably in form and size, and their whole arrangement is irregular throughout. They are sixteen in number, five radial in position, five directed to the anal side, one to each side adjoining the anterior ray, and two to each of the other two interradial sides.

Above the fourth ring, the plates are readily recognized as radials and interradials. In the specimen there are 2×5 radials, and the interradials consist of three to each of the four regular sides, and eight on the azygous side. The two radials connect with the radial plates of the fourth ring only in the anterior ray, in the four other rays they are separated from that ring by two interradial pieces, which join underneath.

In the original description of *Acrocrinus Wortheni*, the plates of the fourth ring were included with the radials and interradials, and the number of the former was given at three in the four

lateral rays, and four in the anterior ray, the number of interradials at six to seven, with eighteen anal pieces.

In this formula, the so-called first radials in four of the rays are laterally separated from the rest by intervening interradial pieces, a very uncommon but not altogether unprecedented occurrence among Palæocrinoids. In *Periechocrinus* the radials are not unfrequently found connected by their angles only, and sometimes, but exceptionally, one of them is altogether separated from the rest by intervening interradial plates. Such a feature, thus widely departing from the usual mode of occurrence, may in certain cases become a fixed and constant character, but it must not be overlooked, that by admitting the plates of this upper ring as radials, it becomes imperative to extend the term radials to every radial plate below, as each one of them is separated from the preceding plate in a like manner. This would increase the number of radials in *Acrocrinus Wortheni* to five (there was evidently a small bifurcating piece filling the concavity of the upper plate) in the lateral rays, and six in the anterior ray, a comparatively small number to what we must expect to find in *Acrocrinus Shumardi*, if we adopt the above interpretation for these plates.

Through the kindness of Prof. Whitfield, we recently had an opportunity to examine three specimens of the latter species from the Museum of Natural History of New York, which have afforded us additional information upon this interesting genus.

Acrocrinus Shumardi is much larger than *Acrocr. Wortheni*, and the calyx is composed of six to seven hundred pieces, while in the latter it has less than one hundred. There are two large basals; two contiguous radials, the lower one small, pentagonal, the other hexagonal with excavated upper side; three interradial pieces arranged as in the preceding species, the larger one resting between both radials of adjoining rays, the two lower ones abutting against the lower sloping sides of the second radials. The above radials and interradials are distinctly separated from the basals by a belt of small hexagonal pieces, which in position are partly radial, partly interradial. They are arranged alternately in rows, those of each successive series comparatively larger; but, while in *A. Wortheni* there are only four rings of from 12 to 14 pieces, Yandell's species has 14 to 20 rings, more or less, and 25 to 30 or more plates in each ring. Counting as before all plates

which are radial in position as radials, and all intermediate plates as interradials, the species possesses 12 and more radials to the ray, and 100 and more plates in each interradial space—an enormous increase over the plates in *Acrocr. Wortheni.* Such a wide difference in the number of interradial plates among species of the same genus is certainly very remarkable, but might be accounted for, as this class of plates is subject to great variation; but a numerical difference in the primary radials, if such was the case, would be exceptional. The primary radials are elements which, once developed, do not multiply, but their number is constant throughout the genus, and we doubt if *Acrocrinus* forms such a remarkable exception to the rule. It seems to us more probable that only the two large, contiguous upper plates, and the small triangular bifurcating piece succeeding them, are radials, that only the three intervening pieces in a lateral direction are true interradials, and that all lower plates, from the basals up, are merely accessory pieces, which obtained their position, whether radial or interradial, accidentally through their alternate arrangement, and the regularity with which they are distributed. By this interpretation the two species, which appeared to be so widely distinct, are brought within the limits of the same rule—both having the same number of radials, interradials and anal plates. It is true that accessory pieces like these are not found dorsally in any other genus of the Palæocrinoidea, but they are not uncommon among Cystideans, and similar plates occur ventrally in some of the larger Actinocrinidæ and Rhodocrinidæ, which, like those of the calyx, increase numerically by age, being represented sometimes by a single ring, and again, in the same species, by a wide belt of pieces. The accessory pieces in *Acrocrinus* increased in number by adding constantly new rings above the basals. This is well shown by the small specimen of *Acrocrinus Wortheni*, in which the plates of the latest ring are yet triangular, only the upper portion being developed; and it is further indicated by the increase in the size of the plates, which is in an upward direction.

In two of the New York specimens, the arms are partly preserved, and in the third one also portions of the vault. *Acrocrinus* had a third primary radial, which had not been observed in *Acrocrinus Wortheni.* It is triangular and resembles the small second radials of *Platycrinus*, resting like those within the con-

cavity of the larger plate. There are also secondary radials, but these extend into free rays.

ACROCRINUS Yandell.

1855. Yandell, Amer. Journ. Sci. and Arts, vol. xx (new ser.), p, 135.
1858. Hall, Geol. Rep. Iowa i, Pl. ii, p. 689.
1882. Wachsmuth, Bull. i, Illinois St. Mus. Nat. Hist., p. 41.

Revised Generic Diagnosis.—Calyx goblet-cup or urn-shaped; composed of a large number of plates, which increase in size gradually from the basals up; plates thin and without ornamentation.

Basals two, comparatively large, either formed into a cup, or thickened at the lower side and extended into a rim; sometimes depressed and in form of a disk. The two plates are about equal, their suture running from the anterior to the posterior side; the upper side not excavated.

Primary radials 3×5, separated from the basals by a belt of numerous, small hexagonal pieces, arranged alternately in rows, those of each succeeding series comparatively larger. The first plate pentagonal, resting with the lower angles between the interradial plates of adjoining fields, the upper side supporting a second radial. Second radials hexagonal, more than twice as large as the first, especially much wider. They abut by their lower sloping sides against the upper interradials, and their lateral faces rest against corresponding plates of adjoining rays, except toward the posterior side, where an anal plate intervenes. Their upper sides are truncate and somewhat excavated. The third radials are axillary, very small, triangular, sometimes but partly occupying the concavity of the preceding plate. The higher orders of radials, so far as known, are extended into free rays as in *Platycrinus.* There are $2 \times 2 \times 5$ secondary radials, which rest obliquely against the sloping sides of the triangular piece. They are short but wide; their inner sides connected by a suture, the outer side partly placed against a second primary radial, filling part of its concavity, and partly extended beyond it. In *Acrocr. Shumardi*, the outer pair of secondary radials gives off an arm; the inner division bifurcates again at the second plate, and supports 2×2 tertiary radials with an arm each, thus giving three arms to each main division, and six to the entire ray. The arm formula, however, may vary in other species.

Arms long, of nearly equal thickness throughout their length. They are composed of two series of very short pieces, alternately arranged. Ventral furrow wide and deep. Pinnules long, closely packed together, composed of six to seven joints, three times longer than wide.

Interradials three, in two series; the first series composed of two plates, which rest upon the belt of the supplementary intervening pieces already described, and between the sloping sides of the second radials. The second series consists of a single piece, placed between the upper sloping sides of the first radials, and the lower sloping sides of the second radials. The azygous side is known only in *A. Wortheni.* In that species it is composed of two hexagonal anal plates, resting upon a row of similar pieces, which, like those, are longitudinally arranged. The upper anal plate is placed in line with the second primary radials, and is higher, but not quite so wide; the second plate is somewhat smaller. At each side of the anal plates there are three interradials, which are formed and arranged like those of the four other sides.

The ventral covering is but imperfectly known; we only observed numerous thin, very minute, irregular pieces, with an elevation toward each ray. Position and form of the anus unknown.

Column round, somewhat tapering downward, composed of thin joints; central canal small.

Geological Position, etc.—*Acrocrinus* is the last and only surviving genus of the Camarata at the close of the subcarboniferous. It has been found only in the Mississippi valley, where it is exceedingly rare.

1855. **A. Shumardi** Yandell. Type of the genus, Amer. Journ. Sci. and Arts, vol. xx (new ser.), p. 135 with figure. (It was previously figured without description or name by Yandell and Shumard, 1847, in their Contrib. Geol. Kentucky, Pl. 1, fig. 3).—Chester or Kaskaskia limest. Grayson Co., Ky.

1858. **A. urnæformis** Hall. Geol. Rep. Iowa, i, Pl. ii, p. 690, Pl. 25, fig. 11 a, b.—Chester or Kaskaskia limest. Pope Co., Ill.

1882. **A. Wortheni** Wachsmuth. Bull. i, Ill. St. Mus. Nat. Hist., p. 41; also Geol. Rep. Ill., vii, p. 343, Pl. 30, fig. 13.—Coal measures. Peoria Co., Ill.

FAMILY IX.—BARRANDEOCRINIDÆ Angl.

BARRANDEOCRINUS Angl.

This is one of the most remarkable forms of the Palæocrinoidea. Looking at a perfect specimen with all its arms intact, it super-

ficially resembles a Blastoid. However, with the arms removed, it is found to possess all the essential characters of the Actinocrinidæ, and doubts might be entertained whether it should not be grouped with that family. Angelin and Zittel have made it the type of a distinct family, and we think the peculiar construction of the arms and ventral side fully justifies this separation. The arms of *Barrandeocrinus*, if we correctly understand the figures, were permanently in a recumbent state or moved with great difficulty; they were laterally connected at the tips of their pinnules, at least those of the same ray, and could not be closed in the usual way.

Generic Diagnosis.—In its general outline, with the arms attached, resembling a Blastoid; form globose; calyx, without arms, cup-shaped. Arms arranged in pairs; recumbent; their dorsal side directed toward the calyx, the ventral side exposed to view. They are united laterally by the tips of their pinnules so as to completely cover the calyx, and extend beyond it to the upper part of the column, which is somewhat indented for their reception.

Basals three, equal. Primary radials (?) 3×5,[1] the first considerably larger. The axillary radials support at each upper side a single rather large secondary radial, and these support an arm each. Interradials arranged as in the Actinocrinidæ; the four regular sides, up to the arms, consisting of only one plate, which rests upon the first radials. The axygous side has two large anal plates; the lower one meeting the basals, the other placed between the interradial which is bisected for its reception. These are succeeded by three much smaller and elongate interradial plates, and a similar number of interaxillary pieces of exactly the same form and arrangement as the three interradial ones. Ventral surface deeply depressed along interradial and interaxillary spaces, the depressions which grow deeper toward the equatorial zone alternating with ten flattened ridges which led to the ten arms.

Arms heavy; composed of a single row of closely set, quad-

---

[1]Angelin states that the number of radials is 2×5, while Zittel gives it as 3×5. In Angelin's figure, Icon. Suec., Pl. v, figs. 6, 6 a, there appear to be but two primary radials, the second plate being axillary. But in the specimens represented on Pl. iv., fig. 5 a, and Pl. xxii, fig. 3, three of them are visible, arranged as those of *Actinocrinus*. It is probable that the true number is three, and that in the first mentioned specimen the sutures between the second and third radials became obliterated by anchylosis.

rangular plates, with strong, apparently immovable pinnules, laterally connected. The arms are so closely folded together that they appear as if they were suturally connected, and formed around the calyx a solid body with ten ambulacra upon the surface.

Column stout, circular, with pentangular axial canal.

The only known species is:

1878. **Barrandeocrinus sceptrum** Angl. Icono. Crin. Suec., p. 8, Pl. 4, figs. 5, 5 a, and Pl. 5, figs. 6, 6 a, and Pl. 22, figs. 2-4.—Upper Silur. Gothland, Sweden.

FAMILY X.—CALYPTOCRINIDÆ Roemer.

Roemer, in proposing this family, used the name Eucalyptocrinidæ (Leth. Geogn., Aug. 3, 1855, p. 229), which was afterwards changed by Angelin to Calyptocrinidæ (Icon. Crin. Succ., 1879, p. 14). The latter name was accepted by Zittel, who referred to it also Lyriocrinus Hall, which we have placed under the Rhodocrinidæ.

EUCALYPTOCRINUS Goldfuss.

(**HYPANTHOCRINUS** Phillips.)

1826. Goldfuss. Petref. Germ., i, p. 212.
1835. Agassiz. Mem. Soc. des Sci. natur. de Neuchatel, i, p. 197.
1838. Goldfuss. Nova Acta. Leopold., xix, i, p. 335.
1841. Müller. Berl. Acad. d. Wissensch., p. 210.
1841. Hall. Paleont. N. York, ii, p. 207.
1843. Roemer. Rhein. Nebergangsgeb., p. 64.
1850. D'Orbigny. Prodr. de Paléont., i, p. 45.
1852. Quenstedt. Handb. der. Petrefactenk., p. 624.
1854. McCoy (in part). Synops. Brit. Palæoz. Fossils, p. 57.
1855. F. Roemer. Lethæa Geogn. (Ausg. 3), p. 257.
1857. Pictét. Traité de Paléont., iv, p. 307.
1860. Bronn. Klassen des Thierreichs (Actinozoa), Pl. 27.
1862. Hall. Notice of New Foss. from Waldron, p. 3.
1862. Dujardin and Dupé. Hist. natur. des Zooph. Echin., p. 115.
1865. Hall. 15th Rep. N. Y. State Cab. Nat. Hist. p. 32.
1866. Schultze. Monogr. Echin. Eifl. Kalk., p. 90.
1878. Angelin. Iconogr. Crinoid. Suec., p. 16.
1879. Hall. 28th Rep. N. Y. State Cab. Nat. Hist. (edit. ii), Pls. 16-19.
1879. Wetherby. Journ. Cincin. Soc. Nat. Hist. (April), No. 5.
1879. Zittel. Handb. der Paleont., i, p. 379.
1882. S. A. Miller. Journ. Cincin. Soc. Nat. Hist. (July).
(?) Syn. *Hypanthocrinus* Phill., 1839; Murchison's Silur. System, p. 672, Pl. 17, fig. 3; Zittel, 1879; Angelin, 1878; S. A. Miller, 1880.

There is some doubt whether *Hypanthocrinus* Phillips is a synonym of *Eucalyptocrinus* or a good genus. *Hypanthocrinus* was separated by Phillips simply upon the presence of a column, which Goldfuss thought to be absent in *Eucalyptocrinus*, but as *E. rosaceus*, his type is known to be pedunculated, this distinction fails. Angelin and Zittel, who both uphold *Hypanthocrinus*, describe the base as being less deeply funnel-shaped, the anal tube as extending beyond the arms, and the partition walls surrounding the arms as being constructed principally of a single piece. A critical comparison has convinced us that these characters are not constant throughout the species. The only character upon which a separation might possibly be effected, is the proboscis-like anal tube, but this part, unfortunately, is rarely preserved. Some of the American species with a long tube have a deep, funnel-shaped base, while in others with a simple opening, the base is comparatively shallow. In all of them the partition walls between the arms consist of two pieces, but in some species the lower one is comparatively longer than in others. We shall ignore *Hypanthocrinus* until better distinctions are given.

Eucalyptocrinus is closely allied to *Callicrinus*, from which it differs in having rudimentary partitions between the arms, extending out only a short distance, leaving the greater part of the arms free and unprotected.

Among the species that have been referred to *Eucalyptocrinus*, are several which were described from natural casts. We do not deny that their generic relations were correctly identified, nor that differences of specific value probably exist among them, but we doubt if it is possible for any one to decide from internal casts whether such specimens are specifically distinct from others in which the test is preserved, and hence consider them for the present as doubtful species.

Troost's *Eucalyptocrinus conicus*, *E. extensus*, *E. gibbosus*, *E. Goldfussi*, *E. lævis*, *E. Nashvillæ*, *E. Phillipsii* and *E. Tennesseæ*, all from the Niagara of Western Tennessee, are mere catalogue names, no descriptions having been published.

Generic Diagnosis.—When the arms are attached more or less ovoid; without arms resembling a wine bottle with concave bottom and long slender neck. The neck is surrounded by ten partitions, arranged vertically so as to form ten niches or compartments for the reception of the arms. The calyx is composed of

heavy plates, is either cup- or saucer-shaped, with basal regions deeply concave, somewhat funnel-shaped. In the dorsal cup the pentamerous symmetry is interrupted by the basals only; at the ventral side, however, it is greatly disturbed. Anus central, located at the top of the neck-like prolongation, or at the end of a tube.

Basals four, small, unequal in size, one of them larger than the rest; axial canal five-rayed; its radii directed interradially, there being two of them in the larger plate. As a rule the basals are not seen externally, being placed at the upper end of the concavity, which also involves the greater part of the first radials, and frequently other plates.

Radials in three orders, the tertiary radials, however, imperfectly developed, and taking rather the form of brachials. Primary radials 3×5; the first one large, wider than the other two; the second quadrangular, wider than high; the third hexagonal, its upper side truncate for the reception of an interaxillary plate. Secondary radials $2 \times 2 \times 5$, all pentangular, the lower series larger than the upper, those of the same division connected by horizontal suture. The upper secondary radial is axillary, and supports the tertiary radials, which are composed of two short transverse pieces supporting the arms.

Dorsal interradials three to each interradius, throughout the genus, in young as well as in adult specimens. The lower one is the largest plate in the calyx, and always decagonal. The two upper plates are connected by a vertical suture to their full length, and both combined are smaller than the lower one. Their upper ends form a narrow quadrangular projection, which extends to the top of the tertiary radials, and supports upon its truncate upper side the interradial partition walls. The interaxillary plates of the dorsal side consist of a single piece in each ray, placed between the secondary radials. In form and dimensions it resembles most remarkably the two upper interradial plates, its upper end projecting in a similar manner to the top of the tertiary radials, and also supporting a partition. The peculiar projections between the arm sockets give to the specimen a very marked appearance, and when the ventral side is not preserved, form a reliable guide for generic identification.

The ventral side consists of four rings of plates. The lower ring is composed of five elongate interradials, which rest upon

the projecting faces of the interradials at the dorsal side. There are five interaxillary plates of a similar form, supported by the dorsal interaxillaries, and ten small triangular interbrachial pieces, interposed in such a manner between the foregoing plates that always an interradial and an interaxillary meet laterally above an interbrachial. The second and third rings consist of four plates each; the fourth of ten. The two former ones together form the neck-like prolongation of the body, and the plates of the fourth ring, combined with those of the first ring, the partition walls encasing the arms.

The interradials and interaxillaries of the first ring are uniform in size and shape; they are knife-like, their blunt sides exposed to view, their sharp edges turned inward. Toward the lower end where the plates decrease in depth, lateral flanges project out from their inner edges, which unite suturally, and enclose the visceral cavity, while the knife-like outer portions, as we understand it, are merely extraordinary protuberances, like the nodes or spines in some Actinocrinidæ, but forming by means of their connected wing-like extensions a cover or protection for the arms.

The plates of the second ring fit into the ten angles formed by the preceding plates, but do not alternate with them. Two of them are a little wider, and these are alternately arranged with the smaller ones. The two narrower plates are generally longer, angular above, while the two others are truncate, and their lateral faces slightly sloping upward. When united, they form a funnel with the narrow opening upward. Transversely they form a ring with ten protuberances, which on their outer surface represent longitudinal ridges. The ridges correspond in position with the interradial and interaxillary partition walls which overlap them, while the alternate grooves form the inner angle of the niches.

The third ring, like the second, consists of four plates, but these, as a rule, are not so large, and have a more irregular arrangement; two of them are generally shorter, and do not touch those of the preceding ring. They are provided at their outer faces with ten longitudinal ridges, which, to their full length, are overlapped by the partition walls, which extend downward from the fourth ring of plates.

The plates of the fourth ring are constructed upon a similar plan as those of the first ring. Like those, they consist of ten

pieces, but they undergo more variations among species, and show more irregularities than any of the other plates. In some species they are confined almost exclusively to the upper face, being mere top pieces; in others they represent an important part in the partition walls, while in still others they extend deeply down into the tubular neck, forming the upper part of its walls. In all cases, however, their obtuse edges are turned outward, and form the upper part of the partition, being suturally connected with the lower part of them.

The plates covering the tubular neck, *i. e.*, anal plates, consist of small pieces, with a somewhat subcentral opening, or, as in *Eucalyptocrinus rigens* Angelin, of valvular plates. Sometimes they are extended into a free tube, composed of hexagonal pieces. The arrangement of the plates surrounding the anal opening is more regular than it appears from some specimens. The apparent irregularities are caused largely by the plates of the third ring, which, in some species, have their upper ends partly exposed.

The arms are arranged in pairs, each pair filling one of the ten compartments, with an interradial partition wall on one side, and an interaxillary one on the other. The arms evidently moved with difficulty, being heavy, and in the adult composed of two rows of short transverse pieces, with horizontal sutures, but there was a single row of wedge-shaped pieces in young specimens. They have a deep ventral furrow, and long pinnules composed of numerous joints, which gradually decrease in width. The arms and pinnules are so closely fitted into the partition walls, that when the arms are perfectly closed, it appears as if they were suturally connected and constituted a part of the body.

The visceral cavity actually is formed only by the plates of the dorsal cup and by the two lower rings of plates in the vault, the plates of the two upper ones forming the neck-like prolongation. The food grooves enter the calyx at the base of the arms, and proceed within shallow grooves at the inner floor to near the top of the second ring. The hydrospires evidently extended to the lower portion of the neck, and perhaps (?) communicated with the exterior through the anal aperture, as apparently no other opening except the ambulacral passages enter the body.

The column is moderately large, cylindrical, composed of rather long joints, with pentapetalous central canal. It evidently had no lateral cirrhi, except at the root, where it gives off hundreds of

little rootlets, which gradually taper, spreading out horizontally.

Eucalyptocrinus is one of the most perplexing genera, especially by reason of its peculiar ventral structure. The only ventral plates about which there seems to be no doubt are those of the first ring, which have been designated by all writers as large interradials and interaxillaries, *i. e.*, interdistichalia. More dubious are those of the second ring, which partly cover the peristome. They fit with their projecting angles into the ten re-entering angles formed by the sloping sides of the preceding plates. The plates of the one ring practically alternate with those of the other, for by bisecting the two smaller plates, and dividing the larger ones into three pieces, we obtain ten nearly equal plates, alternately arranged, thus proving that the plates are not in part interaxillaries; but what are they? We doubt if they are calyx interradials; the fact that there are four plates is certainly a very serious objection. By dividing the plates among the five interradii, some of the pieces would be distributed among different areas. Another interpretation seems to us more probable, and offers at the same time an explanation of the plates in the third ring.

The proximals and the oral plate, in all Palæocrinoids with nearly central anal tube, are pushed to the anterior side, and the oral plate and the two smaller proximals constitute actually a part of the tube of which the four larger proximals form the base. We think the case is very similar in *Eucalyptocrinus*, but here, owing to the strictly central position of the anal tube, not only one of the proximals, but also the oral plate is penetrated by the anal passage, and divided into two parts. This, if correct, suggests that in *Eucalyptocrinus* the four plates of the second ring represent the four large proximals, a view which seems to be confirmed by the peculiar arrangement of the plates in the third ring, in which we consider that the two smaller ones represent the two smaller proximals, while the two larger pieces, which rest upon all plates of the second ring, are equivalent to the oral plate. This would further suggest, that the ten plates in the fourth ring are extravagantly developed anal plates.

Geological position, etc.—*Eucalyptocrinus* is one of the leading genera of the Upper Silurian, and it occurs in America and Europe. A single species is known from the Devonian.

The following species have been described :—

(?) 1865. **Eucalyptocr. chicagoensis** Winch. & Marcy. Mem. Bost. Soc. Nat. Hist., vol. i, No. 1, p. 90.—Niagara gr., Chicago, Ill. (Described from casts.)

1843. **E. cœlatus** Hall (**Hypanthocrinus cœlatus**). Geol. 4th Distr. N. Y., p. 113, fig. 1.—F. Roemer, 1855, Leth. Geogn. (Aug. 3), p. 260. **E. cœlatus** 1852, Hall, Palæont., N. Y., p. 210, Pl. 47, figs. 4 *a–c;* F. Roemer, 1868, Silur. Fauna West. Tenn., p. 48, Pl. 4, fig. 3; Hall, 1865, Trans. Alb. Inst. (Abstr., p. 32); also 20th Rep. N. Y. State Cab. Nat. Hist., pp. 321–329 (Revised Edit., pp. 363–366); 28th Rep. N. Y. State Cab. Nat. Hist., p. 142, Pl. 16, figs. 1–10, and Pl. 19, figs. 1–3; also 11th Ann. Geol. Rep. Indiana, p. 274, with plates.—Niagara gr. Lockport, N. Y.

(?) 1864. **E. cornutus** Hall. New or little known Foss. Niagara gr., p. 18; also 1865, 18th Rep. N. Y. State Cab. Nat. Hist., p. 322, Pl. 11, figs. 8–10.—Niagara gr. Waukesha and Racine, Wisc. (Described from casts.)

Var. excavatus Hall, 1864. New or little known Foss. Niagr. gr., p. 18; also 18th Rep. N. Y. State Cab. Nat. Hist., p. 322, Pl. 11, figs. 8–10.—Niagara gr. Racine, Wisc.

1879. **E. constrictus** Hall. Trans. Alb. Inst., vol. x (Abstr., p. 10); also 11th Ann. Geol. Rep. Indiana, p. 273, Pl. 15, fig. 1.—Niagara gr. Waldron, Ind.

1863. **E. crassus** Hall. Trans. Alb. Inst., vol. iv, p. 197; 18th Rep. N. Y. State Cab. Nat. Hist., p. 323, Pl. 11, figs. 2, 3 (Revised Edit., p. 365); also 28th Rep. N. Y. State Cab. Nat. Hist., p. 141, and Pl. 17, figs. 1–11, and Pl. 18, figs. 1–9; also Pl. 19, figs. 2, 4, 5; Eleventh Ann. Rep. Indiana, 1851, p. 27, Pl. 17, figs. 1–11, and Pl. 18, figs. 1–9; Geol. Surv. Ohio, Paleont., ii, p. 129, Pl. 6, fig. 11 (Green Co., O.).—Niagara gr. Waldron, Ind.

1839. **E. decorus** Phill. (**Hypanthocr. decorus**) Murch. Silur. Syst. p. 672, Pl. 17, fig. 3; also Hall, 1843, Geol. 4th Dist. N. Y., p. 113, figs. 2–3. **Eucalyptocr. decorus** Hall, 1852, Paleont. N. Y., vol. ii, p. 207, Pl. 47, figs. 1–3; and Pl. 85, fig. 7; also McCoy, Synops. Brit. Palæoz. Foss, p. 58; also F. Roemer Leth. Geogn., 1855 (Aug. 3, p. 259); Dujardin and Hupé, 1862, Hist. natur. des Zooph. Echinod., p. 116.—Rochester and Lockport, N. Y., and Dudley, Engl. (?)

1878. **E. decoratus** Angelin. Iconogr. Crin. Suec., p. 17, Pl. 5, figs. 4, 4 a.—Upper Silurian. Gothland, Sweden.

(?) 1880. **E. depressus** S. A. Miller. Journ. Cincin. Soc. Nat. Hist. (October), Pl. 7, figs. 1, 1 a.—Niagara gr. Chicago, Ill. (Described from a cast.)

(?) 1880. **E. Egani** S. A. Miller. Journ. Cincin. Soc. Nat. Hist., vol. iii, Pl. 4, fig. 1. —Niagara gr. Chicago, Ill. (Described from casts.)

1878. **E. excellentissimus** Angelin. Iconogr. Crin. Suec., p. 16, Pl. 24, fig. 15.—Upper Silurian. Gothland, Sweden.

1847. **E. granulatus** (Lewis) Morris (**Hypanthocr. granulatus**). London Geol. Journ., Part 3, p. 99, Pl. 21, figs. 1–5; also Angelin, Iconogr. Crin. Suec., 1878, p. 18, Pl. 6, figs. 3, 4; also Pl. 24, figs. 10–12; and Pl. 29, figs. 69, 70–74.—Upper Silurian. Walsall, Engl., and Gothland, Sweden.

1875. **E. magnus** Worthen. Geol. Rep. Illinois, vol. vi, p. 501, Pl. 25, fig. 3.—Niagara gr. Wayne Co., Tenn.

*1878. **E. minor** Angelin (**Hypanthocr. minor**). Iconogr. Crin. Suec., p. 17, Pl. 6, fig. 1; also pl. 24, figs. 9–13.—Upper Silurian. Gothland, Sweden.

(?) 1864. **E. obconicus** Hall. New or little known Foss. Niagr. gr., p. 19; also 1865, 18th Rep. N. Y. State Cab. Nat. Hist., p. 323, Pl. 11, fig. 1.—Niagara gr. Racine, Wisc. (Described from internal casts.)

(?) 1861. **E. ornatus** Hall. Rep. of Progress of Geol. Surv. Wisc., p. 20.—Niagara gr. Racine, Wisc. (Described from internal casts.)

1850. **E. ovalis** Troost. Proc. A. A. A. Sci., p. 60; Hall, 1876.

(**E. ovatus** Hall. Not Angelin, was printed in place of **E. ovalis.**) Doc. Edit., 1878, p. 143, Pl. 17, figs. 12, 13; also 11th Ann. Geol. Rep. Indiana, with plates.—Niagara gr. Waldron, Ind.

1878. **E. ovatus** Angelin. Iconogr. Crin. Suec., p. 17, Pl. 5, figs. 1, 2.—Upper Silurian. Gothland, Sweden.

1852. **E. papulosus** Hall. Paleont. Rep. N. York, vol. ii, p. 211, Pl. 47, figs. 5 a, b; also F. Roemer, Leth. Geogn., 1855 (Aug. 3, p. 260).—Niagara gr. Monroe Co., N. Y.

1878. **E. plebejus** Angelin. Iconogr. Crin. Suec., p. 17, Pl. 5, fig. 7.—Upper Silurian. Gothland, Sweden.

(?) 1882. **E. proboscidalis** S. A. Miller. Cincin. Jour. Nat. Hist. (December), p. 224. —Niagara gr. Pontiac, O. (Described from internal casts.)

1860. **E. ramifer** Roemer. Silur. Fauna West. Tenn., p. 51., Pl. 4, fig. 4.—Niagara gr. Decatur Co., Tenn.

*1837. **E. regularis** (Hisinger), **Actinocr. regularis.** Lethæa Suec. (Suppl. 2), p. 6, Pl. 39, fig. 6.—**Hypanthocr. regularis** Angelin, 1878, Iconogr. Crin. Suec., p. 17, Pl. 6, fig. 2; and Pl. 24, figs. 11–20; and Pl. 29, figs. 35–64. Upper Silurian. Gothland, Sweden.

1878. **E. rigens** Angelin. Iconogr. Crin. Suec., p. 17, Pl. 9, fig. 13; and Pl. 24, figs. 16–19–21; and Pl. 29, figs. 30, 31.—Upper Silurian. Gothland, Sweden.

1826. **E. rosaceus** Goldf. (Type of the genus). Petref. German. i, p. 214, Pl. 64, fig. 7; also Nov. Acta Leop. xix, p. 335, Pl. 30, fig. 6. Agassiz, 1835, Mem. des Sci. natur. de Neuchat. i, p. 197; also F. Roemer, Rhein. Nebergangsgeb., p. 64. De Koninck and Lehon, Crinoid. Carb. Belg., p. 73; also Roemer, Leth. Geogn., 1855 (Aug. 3), p. 259, Pl. 4, figs. 20 a–c, and Pl. 4, figs. 11 a–c. Dujardin and Dupé, 1862, Hist. natur. des. Zooph. Echinod., p. 116; Bronn, Klassen d. Thierreichs (Actinozoa), Pl. 27, fig. 2; Pictét, 1857, Traité de Paléont. iv, Pl. c, fig. 1; Schultze, 1866, Monogr. Echin. Eifler Kalk., p. 90, Pl. 11, figs. 1–14.—Lower Devonian. Eifel, Germany.

(?) 1882. **E. rotundus** S. A. Miller. Cincin. Journ. Nat. Hist., vol. v (July), Pl. 3, fig. 4.—Niagara gr. Chicago, Ill. (Described from casts.)

1878. **E. speciosus** Angelin, Iconogr. Crin. Suec., p. 16, Pl. 5, fig. 3, and Pl. 29, figs. 27–29 and 32–34.—Upper Silur. Gothland, Sweden.

1877. **E. splendidus** (Troost) Hall, Geol. Surv. Ohio, Paleont. ii, p. 128, Pl. 6, fig. 12. Niagara gr. Springfield, O.

(?) 1878. **E. tuberculatus** Miller and Dyer, Journ. Cincin. Soc. Nat. Hist. (April), Pl. 2, figs. 9, 9 a.—Niagara gr. Waldron, Ind.—Evidently a mere variety of **E. cœlatus** Hall.

(?) 1882. **E. turbinatus** S. A. Miller, Cincin. Journ. Nat. Hist., vol. v (July), Pl. 3, fig. 5.—Niagara gr. Chicago, Ill.—Described from internal casts.

NOTE.—*Eucalyptocrinus polydactylus* McCoy, is a *Corymbocrinus*, and *E. armosus* McChesney is too imperfectly known for identification.

CALLICRINUS D'Orbigny.

1850. D'Orbigny (*Calliocrinus*), Prodr. i, p. 45.
1878. Angelin (*Callicrinus*), Iconogr. Crin. Suec., p. 14.
1879. Zittel (*Callicrinus*), Handb. d. Paleont. i, p. 378.
Syn. *Eugeniacrinites* Hisinger (not Miller), 1857, Leth. Suec., p. 86.

Callicrinus (*Calliocrinus* d'Orbigny) may be considered as a transition form between *Corymbocrinus* of the Actinocrinidæ and *Eucalyptocrinus*. It possesses the structural peculiarities of the latter, but these are not so distinctly expressed, and it appears as if the genus represented an earlier phase in the development of this family. In both genera, the dorsal and ventral side is composed of plates of a similar kind and like number, and both have partitions ventrally; but, while those of *Eucalyptocrinus* surround the arms on all sides, the partitions of *Callicrinus* are rudimentary, the greater part of the arms being uninclosed.

Generic Diagnosis.—Calyx as in *Eucalyptocrinus*, extending to the tips of arms, resembling a wine bottle with long, slender neck, and deep concavity at the bottom, but the partition walls, in place of forming deep niches, consist only of braces between the arm bases, projecting out between the lower portions of the arms; not extending in height beyond the limits of the first ring of plates. Anus central. The plates are frequently ornamented, sometimes nodose, and certain plates spiniferous.

Form of calyx, number and arrangement of plates as in *Eucalyptocrinus*. Dorsal cup composed of four basals; 3×5 primary, $2 \times 2 \times 5$ secondary, and $1 \times 2 \times 10$ tertiary radials; always 3×5 interradials and one interaxillary. Ventral side composed of four rings of plates; the first ring containing five interradials, five interaxillaries, and ten interbrachial pieces. The interbrachials, as a rule, are somewhat larger than those of *Eucalyptocrinus*, and they are provided, like the interradials and interaxillaries, with a projecting brace, but less prominent than those of the other plates. The latter are always stronger, and sometimes extended into a long spine. The twenty braces or partition walls are arranged parallel to each other, and vertically along the median part of the plates. The second ring, if our interpretation is correct, consists of the four large proximals (compare our remarks in *Eucalyptocrinus*); the third ring of the divided oral or central plate and the two smaller proximals, which agree in their form and arrangement with those in *Eucalyptocrinus*. The plates of

the fourth ring, which form the upper part of the neck, are generally composed of four plates, forming a tubular cavity, which is covered by small pieces surrounding the anal opening. There are no lateral extensions along these plates, but the upper end is frequently provided with a thickened rim, sometimes, however, extended into long spines, which are spread out horizontally.

Arms twenty, not extending beyond the top of the tubular neck; they are composed of two series of interlocking pieces, and are provided with long pinnules, composed of six or more elongate joints. The arms rest within the niches formed by the braces, the greater portion of them remaining free.

Column round, composed of rather long joints with a medium-sized, apparently circular canal.

Geological Position, etc.—*Callicrinus* has been recognized only from the Upper Silurian of Sweden; it is possible, however, that some of the casts described from the Niagara group of Wisconsin represent this genus.

1878. **Callicrinus beyrichianus** Angelin, Iconogr. Crin. Suec., p. 15, Pl. 2, fig. 6.—Upper Silurian. Gothland, Sweden.

1837. **C. costatus** (Hisinger), Eugeniacrinites (?) rostatus, Lethæa Suec., p. 90, Pl. 30, fig. 14 a b; D'Orbigny, 1850, **Calliocrinus costatus** (Type of the genus), Prodrome i, p. 45; Angelin, 1878, **Callicrinus costatus,** Iconogr. Crin. Suec., p. 15, Pl. 1, fig. 6, and Pl. 2, figs. 1–4; Pl. 21, figs. 4, 5; also Pl. 24, figs. 23–26; Pl. 28, figs. 19–22 and 24, 25; also Pl. 29, figs. 1–26 and 65–68.—Upper Silurian. Gothland, Sweden.

1878. **C. diadema** Angelin, Iconogr. Crin. Suec., p. 16, Pl. 28, figs. 27, 27 a.—Upper Silurian. Gothland, Sweden.

1878. **C. koninckianus** Angelin, Iconogr. Crin. Suec., p. 15, Pl. 1, figs. 4, 4 a, and Pl. 28, figs. 18–26.—Upper Silurian. Gothland, Sweden.

1878. **C. minor** Angelin, Iconogr. Crin. Suec., p. 16, Pl. 25, fig. 15.—Upper Silurian. Gothland, Sweden.

1878. **C. murchisonianus** Angelin, Iconogr. Crin. Suec., p. 15, Pl. 1, fig. 3, and Pl, 28, figs. 14–17.—Upper Silurian. Gothland, Sweden.

1878. **C. rœmerianus** Angelin, Iconogr. Crin. Suec., p. 15, Pl. 1, figs. 1, 2, and Pl. 28, fig. 23.—Upper Silurian. Gothland, Sweden.

1878. **C. sedgwickianus** Angelin, Iconogr. Crin. Suec., p. 15, Pl. 1, fig. 5.—Upper Silurian. Gothland, Sweden.

CORRECTIONS.

On p. 252 (Ex. Ed., p. 30), 2d line from bottom, read: "*wholly or partly*" before the word "ventrally."

On p. 268 (Ex. Ed., p. 46), 10th line from top, we stated that Prof. Zittel had been the next writer after Prof. Allman, who acknowledged the presence of orals in *Haplocrinus*, *Coccocrinus*, and the Cyathocrinidæ; we discovered however since that Dr. Carpenter already alludes to them in his paper of April, 1879, while Prof. Zittel's Handbuch der Palæontologie appeared in January, 1880.

On p. 275 (Ex. Ed., p. 53), 9th line from top, read: "*peristomeal area*" in place of "tentacular vestibule."

On p. 280 (Ex. Ed., p. 58), 2d line from bottom, after the word *Allagecrinus* insert the following: "*in which the whole ventral side were constructed of actinal plates.*"

On p. 281 (Ex. Ed., p. 59), 13th line from bottom, read: "the latter are *rarely* perforated" in place of "*not* perforated."

On p. 284 (Ex. Ed., p. 62), 16th line from bottom, in place of "and that these Crinoids possessed an orocentral nervous system like all other Echinoderms, except the Neocrinoidea, in which the nervous system, as now generally admitted, is connected with the chambered organ within the basal cavity," insert the following: "*and that perhaps in these Crinoids, contrary to others, and to the Neocrinoidea generally, the entire nervous system was located at the oral side, in conformity with other Echinoderms.*"

On p. 293 (Ex. Ed., p. 71), 4th line from bottom, in place of "were *covered*" read: "were *succeeded.*"

On p. 294 (Ex. Ed., p. 72), at the top of page, we expressed our surprise that Dr. P. H. Carpenter admitted calyx interradials in *Apiocrinus roissyanus* and not in *A. Meriani*, *A. Rathieri* and *A. murchisonianus*. On pp. 149–151, and also on p. 183 in the Challenger Report, and wherever Dr. Carpenter speaks of calyx interradials in Neocrinoidea, he refers to the genera *Guettardicrinus*, *Uintacrinus* and to *Apiocrinus roissyanus*, without mentioning the three other well-known species, in which plates are distributed interradially likewise, and in a similar manner. All this led us to the conclusion that he regarded the plates of the latter species as wholly perisomic. Dr. Carpenter informed us since that he never held such view, and that he regards the plates in question in all four species as representing substantially the same thing. It must be further stated that Dr. Carpenter admits in *A. roissyanus* as calyx interradials the whole series of plates up to the top of the second radials, and not only the first plate, as we thought to infer from his figure on p. 150, and from his descriptions. We are pleased to make this correction, at the same time we are at a loss to know where the small plates commence to which the letter i alludes, and which, as stated by Carpenter himself (Challenger Rep., p. 150), "pass gradually upwards into those of the ventral side."

EXPLANATION OF THE PLATES.

The following letters are employed throughout all the plates.

a = azygous plates.
b = basals.
br = brachials.
c = column, and sections of the column.
cd = centrodorsal.
cr = compound radial.
d = interaxillaries.
e = covering plates (Saumplättchen).
h = non-arm-bearing radials.
i = interradials (dorsally and ventrally).
o = oral plate or plates.
p = proximals.
r = radials in the calyx and summit.
r^1 = first radial.
r^2 = second radial.
t = plate of the ventral tube.
u = underbasals.
wp = water-pore.
x = anal plates.
xo = anal opening.
xr = posterior radials enclosed in the ring of proximals.
I = interradially.
IX = azygous interradius.

The diagrams on Plate 6 are designed to show the position of basals and underbasals to the different parts of the column; those of Plates 7 and 8, to show the relation of the summit-plates with each other and with adjoining plates.

EXPLANATION OF PLATE IV.

FIG. 1. *Cupressocrinus abbreviatus* Goldfuss, showing the consolidated muscle-plates, the axial canals, arm openings, and the position of the anal aperture.

FIG. 2. Ventral aspect of *Cyathocrinus Gilesi.* The interradials crowned by tubercles, and resting against the incurved ends of the radials.

FIG. 3. Similar view of another specimen, showing the interradials in the same position, but partly covered by perisomic plates, which connect with the outer edges of the incurved ends of the radials.

FIG. 4. Impression of the ventral side of a specimen of *Teleiocrinus.* The radiating ridges represent paired canals along the inner floor of the test. The original is in the collection of Mr. R. R. Rowley.

FIG. 5. Ventral side of *Dorycrinus Missouriensis.* The ambulacral tubes are exposed only close to the arm-bases, disappearing toward the centre beneath the infiltrating material.

FIG. 6. *Cyathocrinus multibrachiatus.* Ventral surface showing the perisomic plates, portions of the interradials, and the summit plates, the latter in process of resorption.

FIG. 7 *a*. A portion of an arm of the same species. Side plates and covering pieces in position (enlarged).

FIG. 7 *b*. A portion of the same specimen still more enlarged.

FIG. 8. Portion of an arm of *Symbathocrinus dentatus*, showing the ventral furrow and its covering.

FIG. 9. Ventral aspect of *Symbathocrinus Wortheni* after removing the upper half of the first brachials.

FIG. 10. Showing the inner floor of the summit plates in *Symbathocrinus Wortheni*. Seen from below, in a transverse section through the first brachials.

FIG. 11. Cross section of arms and ventral tube at a point midway between the base and tips of the arms, from the same specimen.

EXPLANATION OF PLATE V.

FIG. 1. *Haplocrinus mespiliformis* Goldfuss. Ventral aspect, showing the interradials and anal opening.

FIG. 2. Posterior view of the same specimen.

FIG. 3. Distal face of the bifurcating primary radial of *Forbesiocrinus nobilis*, showing its two axial canals.

FIG. 4. Proximal face of the same.

FIG. 5. Lateral face of an interradial of the same species.

FIG. 6. Ventral aspect of an internal cast of *Batocrinus Christyi.* The dark places represent the pillars suspending the perisome, and the radial ridges the subtegminal ambulacral tubes.

FIG. 7. Ventral aspect of *Cyathocrinus iowensis.* All summit plates bisected or partly resorbed.

FIG. 8. Internal view of the central part of the vault, showing a portion of the perisome, and the peristomeal area beneath the centre of the oral plate, whose sutures are visible in the deeply shaded portion. The figure does not show the specimen as far as the arm bases.

FIG. 9. Ventral aspect of an internal cast of *Platycrinus.* The interradials forming a continuous ring around the proximals, surmounting the covering plates, which emerge from beneath the vault close to the arm bases.

FIG. 10. *Belemnocrinus typus* White. Side view of a perfect specimen, showing the porous ventral tube and the arrangement of arms and pinnules.

FIG. 11. *Belemnocrinus florifer* W. & Sp. Side view of type specimen, showing the arrangement of arms and pinnules; the ventral tube, and the position of the cirrhi.

FIG. 12. *Symbathocrinus Wachsmuthi* M. & W. Ventral aspect, showing the arrangement of the summit pieces and the anal plate.

FIG. 13. Side view of the same specimen, showing the proximals and the radial-dome-plates which alternate with small interradials and together with the former plates rest against the muscle-plates.

FIG. 14. Side view of another specimen, showing the summit plates, interradials, portions of the arms and of the anal tube.

FIG. 15. *Catillocrinus Wachsmuthi* M. & W. A nearly perfect specimen with arms, showing the small anterior and one of the large antero-lateral radials.

FIG. 15 *a*. View of the broken upper end of the same specimen, giving a transverse section of arms and ventral tube.

FIG. 16. Side view of another specimen, showing the dorsal side of the large plates composing the anal tube.

FIG. 17. Underbasal disk of *Agassizocrinus*. Ventral view, showing the ramifying furrows toward the basals, and the six pits within the inner cavity.

EXPLANATION OF PLATE VI.

A series of diagrams, showing the position of the lateral cirrhi, that of the axial canals and outer angles of the stem, in monocyclic and dicyclic Crinoids. For better comparison, the upper side is in all these figures interradial, and represents in most cases the azygous side.

FIG. 1. Abactinal aspect of *Xenocrinus*.

FIG. 2. Base of *Reteocrinus*.

FIG. 3. Calyx plates of *Talarocrinus*.

FIG. 4. Calyx plates of *Atelestocrinus robustus*.

FIG. 5. Calyx plates of *Tribrachiocrinus*.

FIG. 6. Base of *Rhodocrinus*.

FIG. 7. Calyx plates of *Carabocrinus*.

FIG. 8. Abactinal aspect of *Millerocrinus Milleri*. After De Loriol.

FIG. 9. Abactinal aspect of *Zeacrinus nodosus*.

FIG. 10. Inner view of the calyx of *Millerocrinus Milleri*, showing the position of the axial canals. After De Loriol.

FIG. 11. Abactinal aspect of the larva of *Antedon rosacea*, shortly before the detachment from the stem. After Dr. W. B. Carpenter.

FIG. 12. Base of *Heterocrinus* and *Stenocrinus*, the column removed.

FIG. 13. Basals of *Stenocrinus*, with a joint of the quinque-partite column.

FIG. 14. Basals of *Heterocrinus*, with a joint of the tri-partite column.

FIG. 15. Basals of *Barycrinus*, with the joint of the quinque-partite column.

FIG. 16. Underbasals and first stem-joint of *Poteriocrinus*.

FIG. 17. Basals and first stem-joint of *Glyptocrinus*.

FIG. 18. Basals and the tri-partite upper part of the stem in *Forbesiocrinus*, *Onychocrinus* and *Taxocrinus*. (The underbasals are covered.)

FIG. 19. Basals and column of *Actinocrinus*, *Batocrinus*, etc.

FIG. 20. Basals and colums of *Megistocrinus Evansii*.

FIG. 21. Basals and column of *Dolatocrinus*.

FIG. 22. Basals of *Eucalyptocrinus and Melocrinus*.

FIG. 23. Inner aspect of the calyx of *Ichthyocrinus burlingtonensis*, showing the position of the small underbasal.
FIG. 24. Basals of *Pentremites*, showing the position of the smaller plate.
FIG. 25. Basals of *Platycrinus*, showing the same thing.
FIG. 26. Basals of *Symbathocrinus*, showing the same.
FIG. 27. Column of *Poteriocrinus and Cyathocrinus Harrisi*, with radial cirrhi.
FIG. 28. Column of *Belemnocrinus florifer* with interradial cirrhi.
FIG. 29. Column of *Cupressocrinus*, showing the position of the peripheral canals.
FIG. 30. Column of *Pentacrinus* with radial cirrhi.

EXPLANATION OF PLATE VII.

These diagrams are designed to show the relation of the summit plates with each other, and with adjoining plates :—

FIG. 1. Diagram of the plates in the early larva of *Antedon rosacea*. After Dr. P. H. Carpenter.
FIG. 2. Summit plates of *Dorycrinus mississippiensis*.
FIG. 3. Ventral aspect of *Eretmocrinus coronatus*.
FIG. 4. Summit plates of *Amphoracrinus spinobrachiatus*.
FIG. 5. Ventral aspect of *Platycrinus glyptus*.
FIG. 6. The same of *Platycrinus subspinosus*.
FIG. 7. The same of *Platycrinus Halli*.
FIG. 8. The same of *Platycrinus tuberosus*.
FIG. 9. The same of *Agaricocrinus Wortheni*.
FIG. 10. The same of a large specimen of *Agaricocrinus americanus*. The dorsal interradials are attached on three sides.

EXPLANATION OF PLATE VIII.

FIG. 1. Internal cast of *Strotocrinus regalis*, showing the impression of the radiating canals along the inner floor of the vault, and the presence of three summit radials between each proximal.
FIG. 2. Internal cast of *Actinocrinus multiradiatus*, showing the same as fig. 1, however, with two summit radials anteriorly and three posteriorly. (The pentapartite protuberance along the oral plate is too prominent in the figure).
FIG. 3. Internal cast of a specimen of *Teleiocrinus*, showing the same as fig. 1.
FIG. 4. Ventral aspect of *Steganocrinus concinnus*.
FIG. 5. Ventral aspect of *Megistocrinus Evansii*.
FIG. 6. Ventral aspect of *Platycrinus burlingtonensis*.
FIG. 7. Ventral aspect of *Marsupiocrinus Tennesseæ*.
FIG. 8. Ventral aspect of *Batocrinus subæqualis*.

EXPLANATION OF PLATE IX.

FIG. 1. Diagram of the calyx plates of *Acrocrinus Wortheni.*

FIG. 2. Interior view of *Glyptocrinus ramulosus.* The specimen is broken in halves, exposing the inner surface of the test, and it shows the continuity of the interradials from the dorsal to the ventral side, the presence of galleries lodging the ambulacra, and the absence of covering pieces in the test; also the apparent existence of a calcareous perisome, supported by pillars as in the Actinocrinidæ.—From a specimen in the Canada Survey Museum.

FIG. 3. Side view of *Zeacrinus nodosus.*

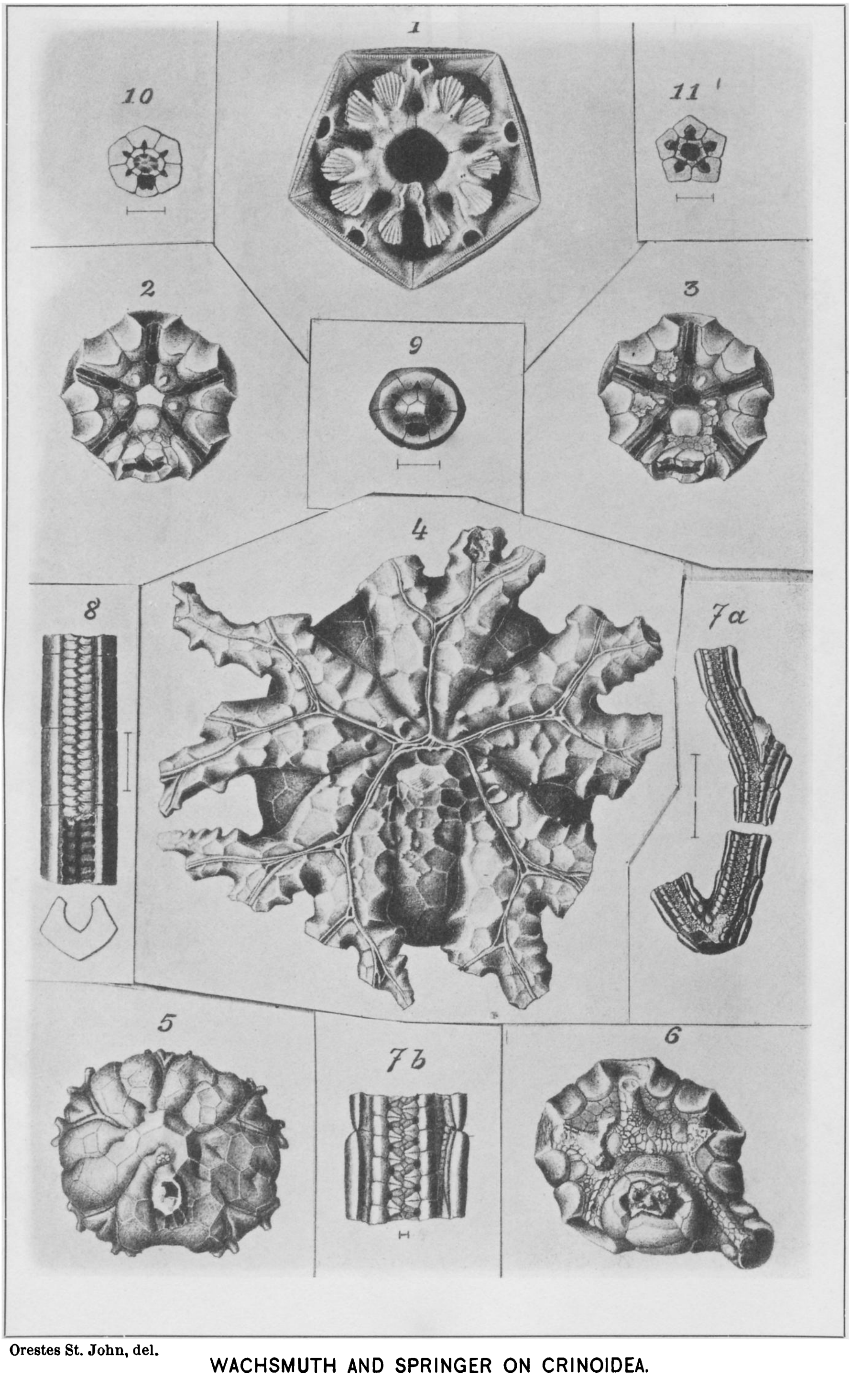
FIG. 4. Side view of *Atelestocrinus robustus.*

FIG. 5. Dorsal aspect of *Cleiocrinus regius.* After a drawing by Mr. Walter R. Billings from type specimen. Basals and underbasals indicated by dotted lines.

FIG. 6. Side view of *Platycrinus burlingtonensis.*

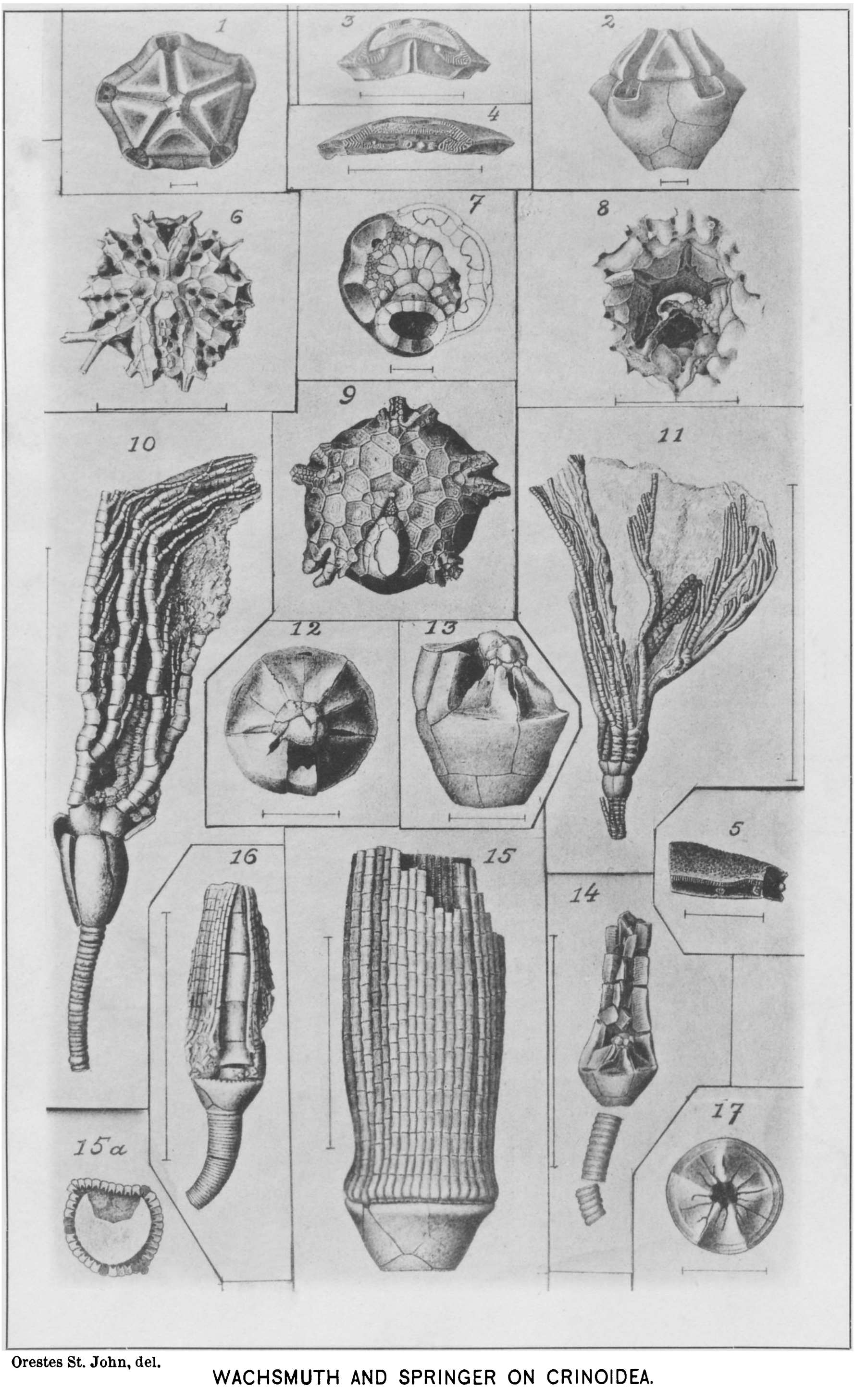
FIG. 7. Side view of *Stemmatocrinus Trautscholdi.*

FIG. 8. Internal view of the same. S. Face for the attachment of the interradials.



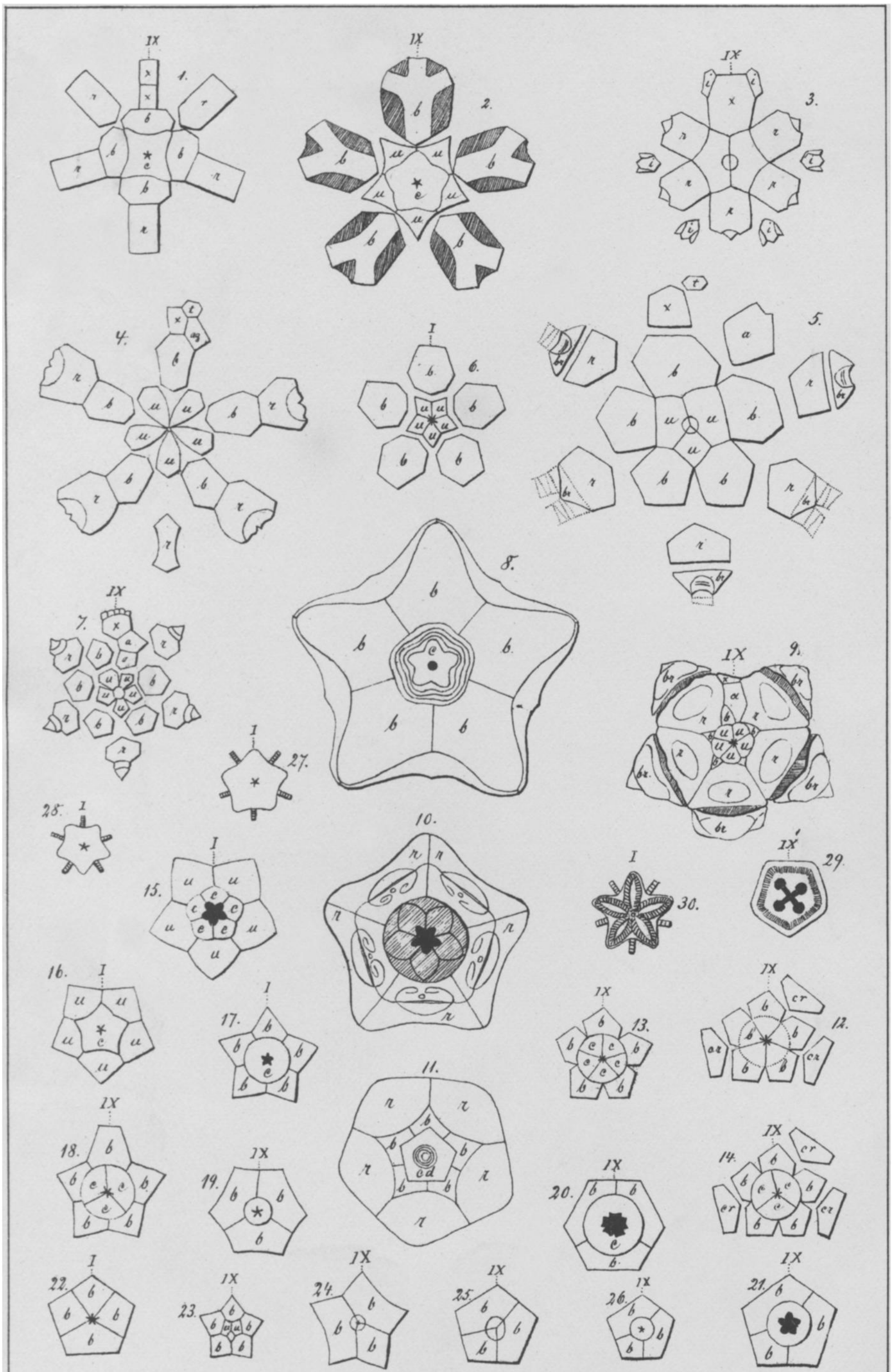
Orestes St. John, del.

WACHSMUTH AND SPRINGER ON CRINOIDEA.

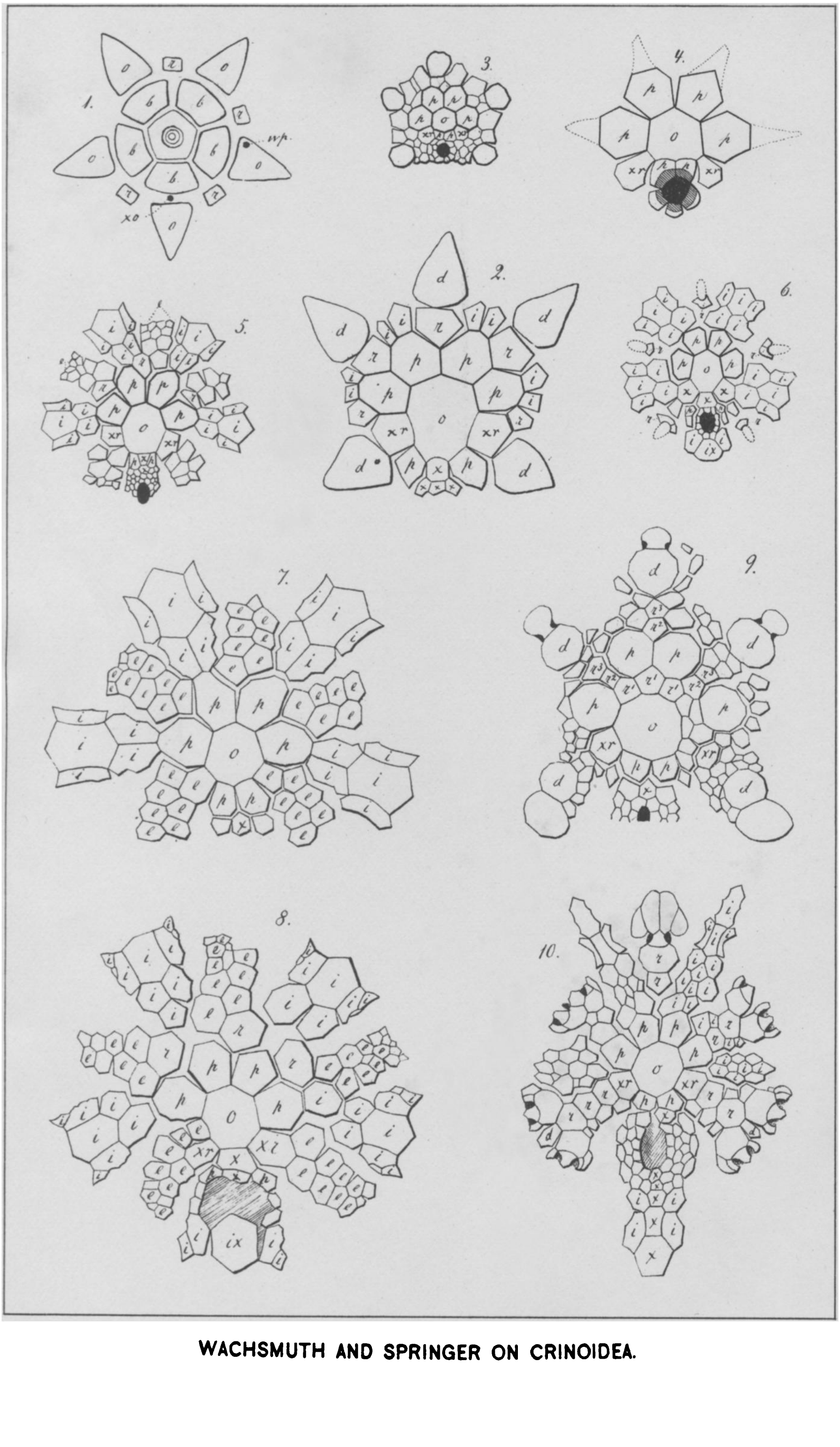


Orestes St. John, del.

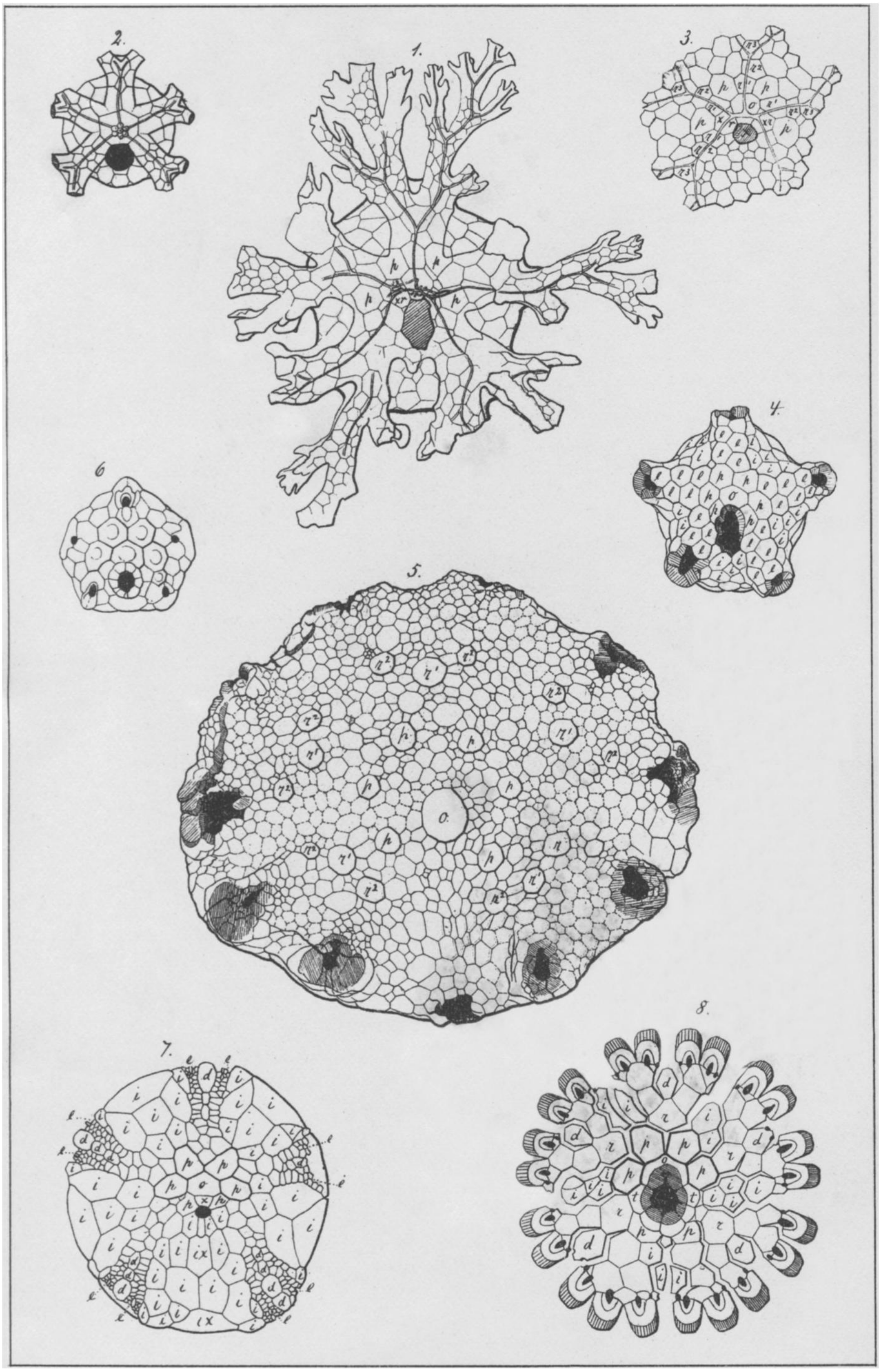
WACHSMUTH AND SPRINGER ON CRINOIDEA.



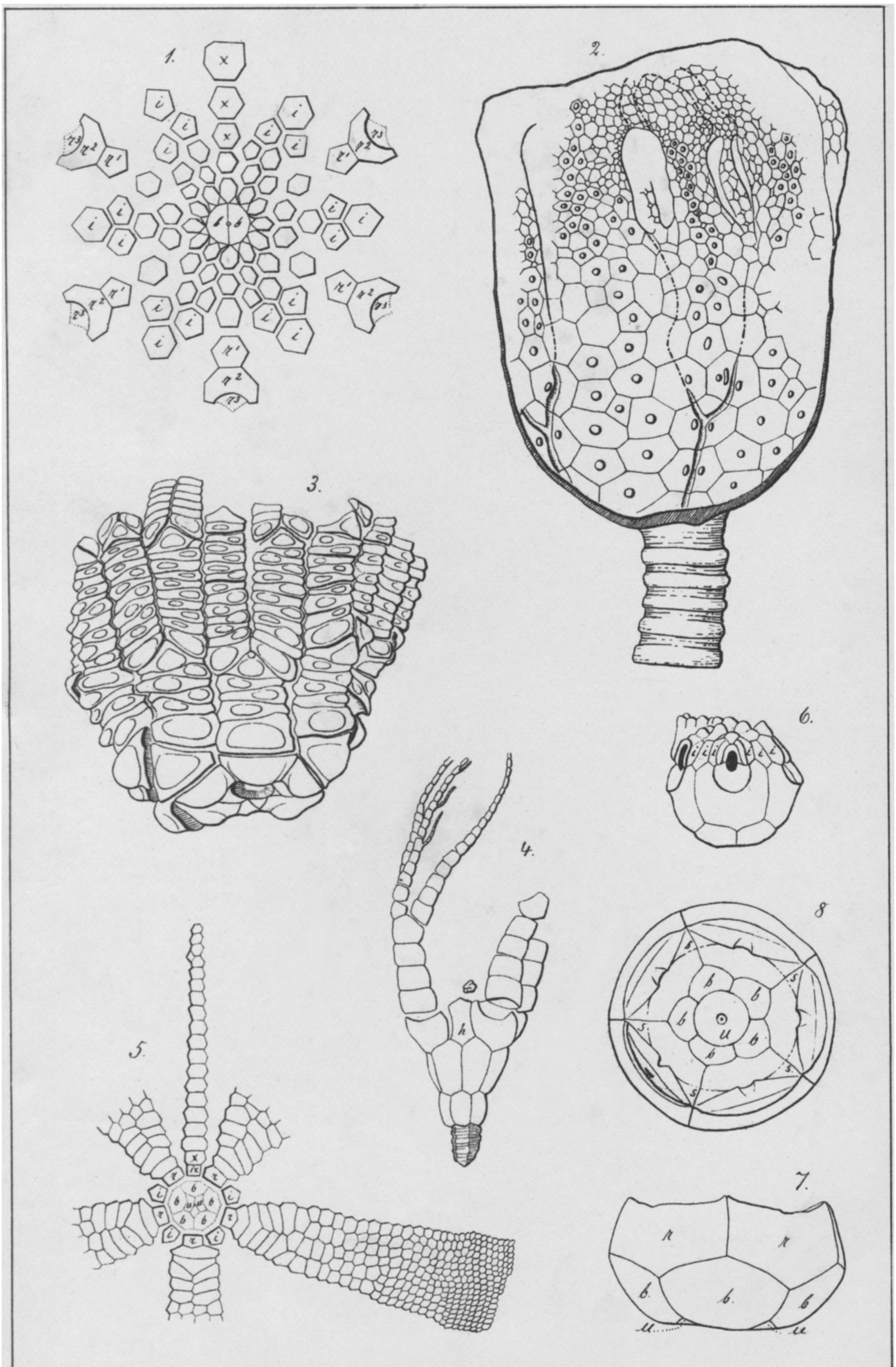
WACHSMUTH AND SPRINGER ON CRINOIDEA.



WACHSMUTH AND SPRINGER ON CRINOIDEA.



WACHSMUTH AND SPRINGER ON CRINOIDEA.



WACHSMUTH AND SPRINGER ON CRINOIDEA.